An Embodiment of Schoenberg's Method of Teaching Musical Harmony in a Guided Discovery Learning Environment

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Abstract

Most traditional musical harmony teaching methods in use in undergraduate courses are centred on pedagogical principles that require students to manipulate musical elements, beyond those directly relevant to the subject matter. Beginning harmony students often encounter extra difficulty in the learning process as they usually lack experience in manipulating individual musical elements. In addition, the emphasis on exemplars of the common practice of eighteenth and nineteenth century composers imposes some limitation on the student's harmonic vocabulary and, in consequence, on the student's creativity.

At the beginning of the twentieth century, Arnold Schoenberg proposed a method of teaching harmony which presented a different set of pedagogical principles: the method required no background knowledge of other musical elements; it encouraged the exploration of the search space of solutions which, in conjunction with a self assessment of them, helps students to develop their own harmonic sense, without the influence of exemplars of the harmonic practice of existing composers. However, although Schoenberg's method addresses the problems presented above, it has not been widely used, mostly because its fundamental pedagogy and curriculum are buried in lengthy philosophical discussions of polemical arguments and criticism of traditional methods.

This thesis investigates the possibility of designing and constructing a computer-based learning environment presenting the pedagogy and curriculum of Schoenberg's harmonic teaching method while remaining true to its spirit. We present a formalisation of part of the method's curriculum and associated pedagogical principles which have been embodied in a prototype learning environment. The results from studies involving the prototype are also presented: a formative evaluation was carried out with music experts aiming to assess its interactive music notation human computer interface and to inform changes and improvements to be made to the prototype; and a summative evaluation was conducted with music lecturers to assess not only the degree of faithfulness of the environment to the method, but also the educational benefits that such an environment can potentially bring to harmony teaching.

The outcome of this research demonstrates that rules and pedagogical principles from Schoenberg's harmonic teaching method can be formalised and are amenable to modelling on a computer. The results of the studies presented here suggest that materials of the method can be delivered, and can be made accessible to the user, by a computer-based environment embodying the computer model introduced above.

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Declaration

I declare that this thesis was composed by myself, that the work contained herein is my own except where explicitly stated otherwise in the text, and that this work has not been submitted for any other degree or professional qualification except as specified.

(*Márcio da Costa Pereira Brandão*)

This thesis is dedicated to my wife Ana, to our sons Pedro and Guilherme, and to the memory of my brother Sérgio.

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Chapter 1

Introduction

Musical *harmony*[1] is a complex subject that requires one to learn how to create and join sounds together in a consistent and musically meaningful way. This creative process is closely related to music composition, which requires from composers the ability to simultaneously manipulate the basic elements of music: *rhythm*, harmony, *counterpoint* and *form*.

The vast majority of harmony teaching methods require students to manipulate, to different degrees, some or all of these musical elements. It is common for beginners to encounter difficulty whilst dealing with them all simultaneously, as they usually lack experience in dealing with them separately. In addition, these methods are centred on melody harmonisation exercises, which not only bring extra difficulties to the learning process (see section 1.3) but also cannot be identified as a legitimate activity of the compositional process:

> *The finished product displays these elements (melody, rhythm, harmony, counterpoint and form) as a unified whole; it does not appear as though, for example, the succession of tones in the melody was conceived first, then a rhythmic element applied to it, and after that a harmonization fitted to the line.*
>
> (Piston, 1978, p. 275)

This research investigates alternative ways to overcome the difficulties that beginners experience while learning harmony. As a consequence of the inher-

[1] An underlined and italicised word or expression indicates the first occurrence of a word or expression that appears in the Glossary.

ent complexity of the chosen domain we first need to present some background knowledge before introducing the argument of the thesis.

1.1 Introducing Harmony

A musical piece may be regarded as having vertical and horizontal dimensions that are directly related to the vertical (*pitch*) and horizontal (*time*) axis within a musical score. The former dimension is associated with the vertical organisation of the notes, that is, how the notes are configured at a given moment or in a particular time interval while the latter dimension deals with the individual *voices* and their movement through time. Figure 1.1 shows two musical events A and B represented in a musical stave, where A occurs before and has a lower pitch than B.

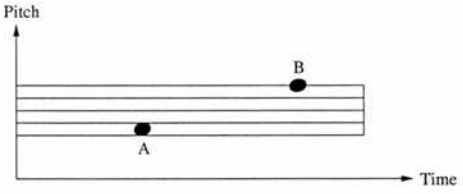
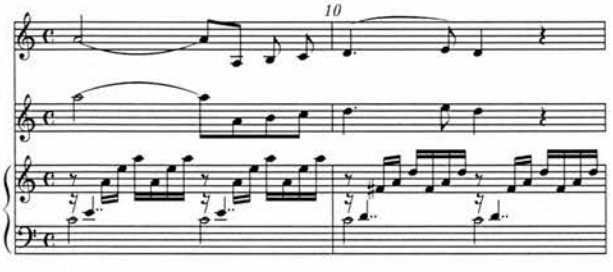
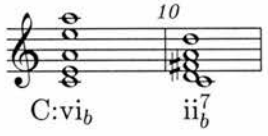


Figure 1.1: Musical events in a musical stave

Figure 1.2(a) shows an excerpt of a musical piece which can be intuitively *abstracted* by means of identifying groups of notes that make part of the same



(a) Excerpt

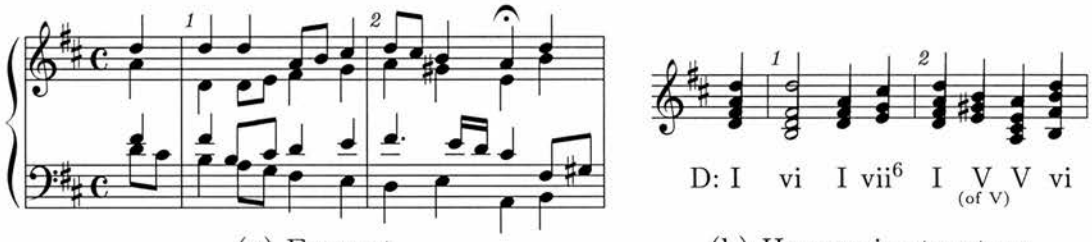


(b) Abstracted representation

Figure 1.2: Excerpt of *Ave Maria* by Charles Gounod, based on the first prelude of Johann Sebastian Bach's *Well Tempered Clavier*

harmonic function, as depicted in Figure 1.2(b). Each group of simultaneous notes is known as a *chord*, which is normally represented as a Roman numeral to designate the *scale degree* – in relation to a particular *key signature* – on which the chord is constructed. The identification of the appropriate grouping of notes is immediate in this case because the original material is made up of *arpeggios*, and there is a direct association between the notes of the original material and the notes of the abstracted representation.

Not all tonal pieces present their harmonic structure as clearly as in Figure 1.2(a). A large amount of tonal compositions contain independent voices that make the harmonic material less clear. However, the harmonic structure still can be abstracted as a sequence of Roman numerals. This sequence represents the scale degrees on which underlying chords, made implicit by the voices acting together, were abstracted. Figure 1.3 shows an excerpt of a musical piece and its abstraction in the same way as above.



(a) Excerpt (b) Harmonic structure

Figure 1.3: Excerpt and harmonic structure of *Chorale Number 16, (Es woll' uns Gott genadig sein)*, from Johann Sebastian Bach

The study of how simultaneous notes can be joined in chords, and how stylistically acceptable sequences of chords can be connected is known as harmony.

1.2 Traditional Harmony Teaching Methods

Traditional harmony teaching methods are centred on the *four-part* harmonisation of given melodies (Piston, 1978; Rockstro, 1881; Gauldin, 1997). The student is required to construct horizontally independent voices that fit into a melody line.

The melody examples try to illustrate the so called harmonic *common practice* of composers of the eighteenth and nineteenth centuries.

Figure 1.4 assumes *homophonic* harmonisation using major chords I, IV and V as a simplification and illustrates the main steps, described below, that students are usually advised to follow when harmonising melodies.

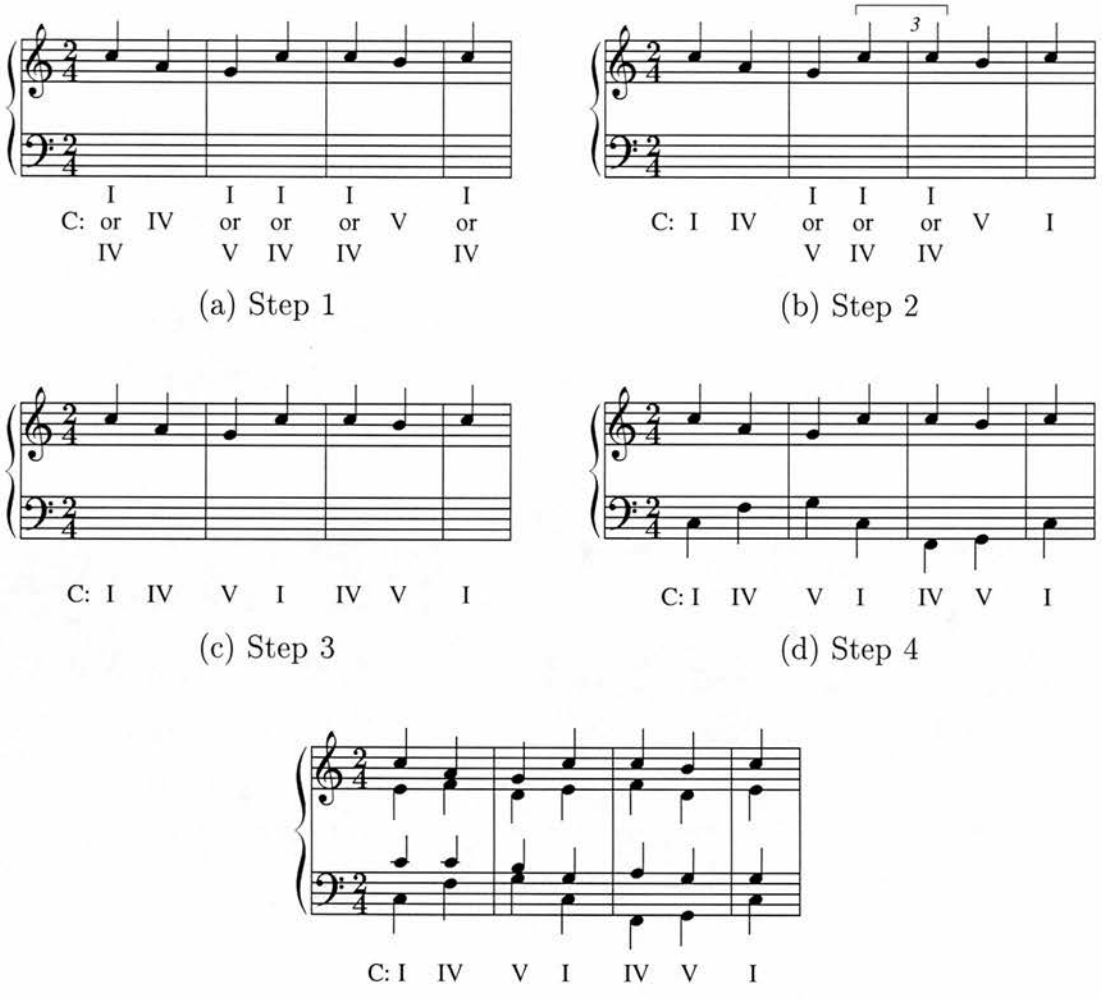


Figure 1.4: Harmonising a melody

Step 1: List all chord choices

All chords that can be associated with each note must be made explicit as Roman numerals. Figure 1.4(a) shows the 32 possible degree sequences for the melody.

Step 2: Refine chord choices

Tonal music pieces almost always start and end at the same *tonic chord* (chord I)[2]. If different start and end chords are eliminated from Figure 1.4 there are still 8 alternative degree sequences remaining, as shown in Figure 1.4(b).

Step 3: Further refine choices

Musical background knowledge is now required to select a musically meaningful chord sequence from the remaining alternatives. This includes considerations such as avoiding the use of the same chord in transitions from a weak to a strong beat, as in the transition from the last beat of bar 2 to the first beat of bar 3 in Figure 1.4(b). Further disambiguation at this stage depends mainly on personal preferences. Figure 1.4(c) shows the chord sequence likely to be chosen by an experienced composer as it contains the largest repeated pattern (of length 3)[3].

Step 4: Define a bass melody

A number of constraints must be simultaneously satisfied: chord sequence, voice range, preferred opposite movement for the soprano and bass voices, provide room for internal voices are amongst them. Figure 1.4(d) shows a choice that satisfies the mentioned constraints.

Step 5: Define the remaining voices

Again a number of constraints must be simultaneously satisfied: chord sequence, voice range, avoid crossing of voices, avoid *parallel octaves* and *parallel fifths* are amongst them. Figure 1.4(e) shows a possible assignment for the internal voices.

The next section addresses the main problems found in traditional harmony teaching methods.

[2]In some cases the *dominant chord* (chord V) can also be used.

[3]Most compositions involves large patterns that are referred to later in the piece. In this particular example the maximum length of non-overlapping patterns for the other chord sequence alternatives (I-IV-I-I-IV-V-I; I-IV-I-IV-I-V-I and I-IV-V-IV-I-V-I) is two.

1.3 Problems with Traditional Methods

The main problems found in traditional harmony teaching methods are:

(a) Background Knowledge

Exercises require students to have considerable background knowledge of other musical elements such as rhythm, counterpoint and form, which adds complexity to the learning process:

> *The book is suitable either for a self-contained course in harmony or for an integrated program combining harmony with other aspects of music. 'Harmony and Voice Leading' touches on many of these aspects, including rhythm, melody, counterpoint and form.*
>
> (Aldwell & Schachter, 1989, p. vi)

> *There are those who consider that studies in harmony, counterpoint and fugue are the exclusive province of the intended composer. (...) First of all, it is clear that this knowledge is indispensable to musicians in all fields of the art, whether they be composers, performers, conductors, critics, teachers, or musicologists.*
>
> (Piston, 1978, p. xix)

(b) Harmonic Analysis of Melodies (Assigning degrees)

Harmonic analysis is the process of assigning degrees to parts of a score. If the score is a single melody, it can accommodate alternative harmonic sequences (as in Figure 1.4(a)), and the selection of the "best" alternative that suits it is the ultimate goal of the analysis process (Figure 1.4(c)). However, beginners usually do not have enough experience for the task, and do not understand what "best" means in this context. So there is a tendency for the teacher to impose on students "acceptable" harmonic sequences:

> *While the harmonisation of a melody or a bass is to a great extent dependent on the musical sensibility of the student, it has to be realised that certain melodic progressions imply, normally, certain definite harmonies, and these implications I have tried to make clear.*
>
> (Lovelock, 1900, Foreword)

In directing the student in the selection of degrees, examples extracted from the music literature of the eighteenth and nineteenth centuries are used together with the composer's harmonic solutions[4]. The teacher defines what is the "best" (or "acceptable") harmonic sequence in relation to the examples. From these examples students are expected to generalise in order to select an alternative for the degree choices that adhere to the common practice of composers of the period.

> *Hence the aim of this book is to present as concisely as possible the harmonic common practice of composers of the eighteenth and nineteenth centuries. (...) The written exercises should be performed as exemplifications of the common practice of composers and not as efforts in creative composition.*
>
> (Piston, 1978, p. xx)

The problem is that students usually incorporate these sequences into their own harmonic vocabulary without further exploration of alternative, and equally acceptable, solutions.

(c) Harmonising a melody (Assigning Notes to Voices)

Having assigned degrees to the melody, notes must be allocated to the remaining voices according to the harmonic analysis (see steps 4 and 5 in Figure 1.4). However, the melody imposes constraints on the task as follows:

- depending on how adequate the harmonic analysis is, it may be difficult, or even impossible, to allocate notes to the voices without violating some of the various musical constraints;
- the number of note allocation alternatives – in relation to a situation without melody – is reduced, which restricts the student's creativity.

(d) Teacher-centred Approach

In traditional methods the teacher usually gives the instructions to a group of students using the common technique of *lecturing* (Peters & Miller, 1982), which involves a discourse given before the class. Usually in these lectures

[4]Most recent texts also includes companion CDs with the audio version of these examples.

excerpts of musical pieces are harmonically analysed, exercises are proposed and some of the student's solutions are corrected. Teachers are largely in control and students have a passive role and less opportunity to directly interact in the instruction being given. A more active role for the student is desirable, but the paradigms which ground traditional teaching do not provide much room for it.

(e) Large corpora of tonal pieces

Traditional methods require a large heterogeneous corpora of excerpts of tonal musical pieces such as sonatas, concertos, and even folk songs. The excerpts illustrate particular harmonic practices, usually by means of comparing their harmonic analysis with the harmonic analysis obtained from harmonisation exercises based on one of their melodies (mostly soprano or bass).

Given the problems of traditional methods, are there alternative teaching harmony methods that address them in a consistent way? More specifically, is there a teaching harmony method that satisfies the following constraints?

(A) Assume less background knowledge, and try to isolate the other elements of music (rhythm, counterpoint and form) as much as possible from the harmony teaching. These other elements are studied in detail elsewhere in the music curriculum.

(B) Guide the student in selecting degrees in exercises that do not require harmonic analysis. This would avoid indoctrinating students with acceptable chord progressions and would let the students practice also alternative chord connections.

(C) Avoid harmonising a melody in order to give students more alternatives in assigning notes to the voices.

(D) Provide a more student-centred approach to teaching in order to maximise the student's creativity.

(E) Avoid a large corpora of (excerpts of) tonal pieces.

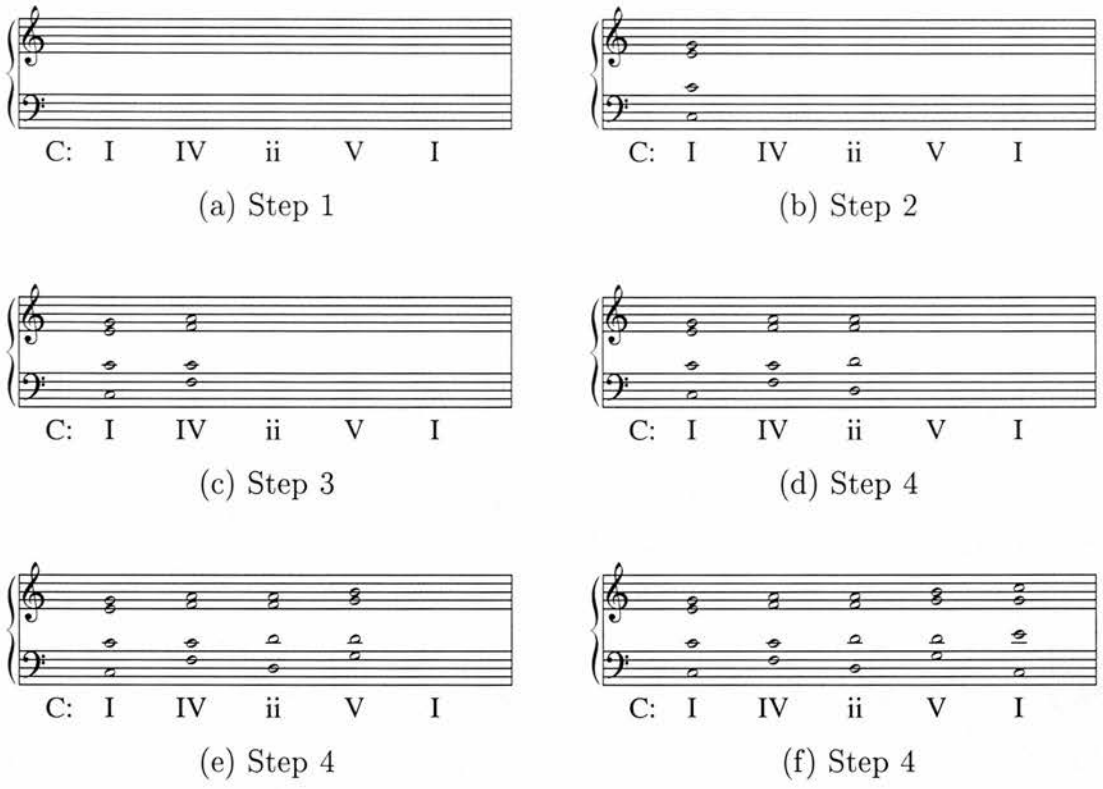
The next section describes the principles on which a couple of alternative harmony teaching methods are based. A method that satisfies constraints (A) to (E) above is presented, and a discussion of how the problems of traditional methods might be overcome is made.

1.4 A Potential Solution: Schoenberg's Method?

There are some alternative harmony teaching methods which follow some of the above principles. For example, there are a number of methods which emphasise technically correct connection of chords without paying too much attention to the other elements of music (constraint (A) in Section 1.3). Hugo Riemann (1895) centred his harmony teaching method around this premise, and he aimed to produce a scientific theory of musical hearing centred around chord progressions involving only three kinds of tonal functions – tonic, subdominant and dominant. However, the emphasis given to these three functions makes it incompatible with constraints (B) and (D) in Section 1.3.

Arnold Schoenberg (1990) also centred his harmony teaching method around technically correct connection of chords. However, he was more concerned in avoiding imposing "acceptable" progressions on students and in giving them more freedom of choice. Schoenberg believed that the student, through experimenting with not only "acceptable" chord progressions and assessing their æsthetics by herself[5], is capable of fostering her own harmonic sense without the strong bias of the harmonic vocabulary imposed by traditional methods. Schoenberg's method is distinguished by a curriculum that does not involve harmonisation of melodies and that incorporates a carefully designed incremental strategy of presentation and practice of new concepts. Figure 1.5 illustrates the main steps, described below, followed by students in the proposed exercises.

[5]The convention followed in this dissertation is to use "she" to refer to the student.



(a) Step 1 (b) Step 2

(c) Step 3 (d) Step 4

(e) Step 4 (f) Step 4

Figure 1.5: Building a chord sequence

Step 1: Chord sequence definition

The student, guided by instructions, selects the degree sequence to work with.

Step 2: Note assignment for chord 1

The student decides the position (see chapter 4) of the initial chord and assigns notes to the voices while observing chord construction constraints.

Step 3: Note assignment for the next chord

The student assigns notes to the chord immediately to the right of the last constructed chord, observing simultaneously the chord construction constraints and the chord connection constraints imposed by the assignment of notes to the previous chords.

Step 4: Repeat Step 3 to all remaining chords

Students repeat step 3 until notes are assigned to all chords of the sequence.

1.4.1 Addressing the Problems with Traditional Methods

The paradigms in which Schoenberg grounded his method address the problems of traditional harmony in Section 1.3 as follows:

(a) Background Knowledge

Schoenberg does not use harmonic common practice examples because the analysis of even simple musical excerpts requires background knowledge of other musical elements. His method does not require that students have as much background knowledge as in traditional methods. In his method, exercises have neither time signatures nor bar separations as the focus is only on harmony, not considering other musical elements:

> *It will lighten the task of both teacher and pupil if everything presented is so clearly coherent that one thing grows out of another. The first necessity then is: to restrict attention to the matter at hand, freeing it from all that is more remote. Therefore, it will surely benefit us here, in the study of harmony, to derive the nature of chord connections strictly from the nature of the chords themselves putting aside rhythmic, melodic, and other such considerations.*
>
> (Schoenberg, 1990, p. 13)

> *The balanced relation of motives to harmony, rhythmic elaboration, in short, what really pertains to composition, if it indeed explained at all, does not belong in a harmony course. The pupil is again learning the unessential! And I cannot understand how he is ever to grasp the essential if the unessential is always given first place in his study.*
>
> (Schoenberg, 1990, p. 16)

(b) Harmonic Analysis

Schoenberg's method is centred on exercises that do not involve harmonic analysis. While students are required to define degrees, they are not constrained to any predefined melody or piece. The degrees are added to a blank stave, and the method provides guidance in the choice of degrees.

> *I have omitted harmonic analyses in this book, because I consider them superfluous here. Were the pupil able to extract from the*

> *musical literature what he needs for composing, then no one would have to teach harmony.*
>
> (Schoenberg, 1990, p. 15)

Schoenberg does not illustrate the harmonic common practice through excerpts of musical pieces, because he thinks that only a full analysis of complete pieces can provide a bigger picture of their harmonic practice.

> *I do not deny that that it would benefit the pupil to account for the harmonic procedure in masterworks. But to do this the way it should be done, i.e. by examining the harmonic structure of an entire work and the significance of the individual chords and chord progressions, would be impossible within the limits of a harmony course. (...) For whenever the pupil has the means to do it himself, he will understand it so much better, just by doing it, than he could by analysis.*
>
> (Schoenberg, 1990, p. 16)

(c) Harmonising a Melody

There are no melodies to be harmonised in Schoenberg's method, as he believes that:

> *First of all: one does not harmonize (a melody), one invents with harmony.*
>
> (Schoenberg, 1990, p. 287)

In fact, more than simply not using harmonisation of melodies as a paradigm, Schoenberg clearly condemns its use on harmony teaching, as shown in the following quotations:

> *.. he decried the usual exercises by which a pupil is supposed to learn harmony: the realization of given figured basses and harmonization of given melodies.*
>
> (Schoenberg, 1990, p. xv, Roy E. Carter's preface)

> *But to invent melodies myself with whose harmonization the pupil is afflicted - I refused to do it, even though I am sure I could invent something better than the miserable stuff certain authors of harmony texts have the nerve to write.*
>
> (Schoenberg, 1990, p. 288)

(d) Teacher-centred Learning

Schoenberg's method is student centred. Students search for solutions to exercises that were formulated by themselves. The main role of the teacher is to guide students in setting up these exercises:

> *I hope my pupils will commit themselves to searching! Because they will know that one searches for the sake of searching. That finding, which is indeed the goal, can easily put an end to striving.*
>
> (Schoenberg, 1990, p. 1)

> *First of all, the pupil should write under [the staff that will carry (the music)], the bass line Roman numerals indicating the degrees of the chords he is to connect; then he should write the bass note of the first chord and go on to complete the first chord by adding the other three voices. Whether it is to be in close or open position with the third, fifth or octave on top - this he will decide for himself, but before he goes to work out the exercise. Thus, he sets up the exercise himself, a procedure we will follow throughout this course of study.*
>
> (Schoenberg, 1990, p. 41)

(e) Corpora of Tonal Musical Pieces

Schoenberg's method does not require a heterogeneous corpora of tonal musical pieces because of its emphasis on chord connections rather than on the common practice of composers from the eighteenth and nineteenth centuries.

1.4.2 Why is the Method not Widely Used?

As shown in the previous section, Schoenberg's method addresses the main problems found in traditional methods. However, its use seems to be restricted to composers and advanced students, as opposed to beginners as originally intended by its author. In fact, to the best of the author's knowledge, Schoenberg's harmony teaching method has not been used as a main reference text for any undergraduate harmony courses that are part of formal music curriculæ.

The main reasons for the method not being widely used within undergraduate harmony courses appear to be identified by Erwin Stein, Schoenberg's pupil and

friend, who wrote in the preface for the *Practical Guide to Schoenberg's Theory of Harmony: A Handbook for Teachers and Pupils*[6]:

> *... In view of the abundance of ideas and the great amount of space taken by theoretical derivations and justifications of the harmonic phenomena, by polemical arguments, and by criticisms of the usual systems of instruction, the use of that book may have been inconvenient for many a pupil who wanted merely to learn or review the handicraft of harmony, or for many a teacher who wanted a facile survey of the material being taught.*

The author believes that the method has rarely been adopted in undergraduate harmony courses, and its use seems to be restricted to more advanced courses as a supplementary text rather than as a core approach. The only two replies to a question posed by the author to a music theory's electronic discussion group (cms-teaching-musictheory@music.org)[7], asking harmony teachers if they were using Schoenberg's method as the main textbook, corroborate this view:

> *Schoenberg's "Theory of Harmony", in my opinion, would not be a workable as an undergraduate harmony text. Its pedagogy is highly idiosyncratic, and there are long polemical and philosophical passages that most students at the stage of first learning harmony would find baffling. That having been said, it is a brilliant book for the reader with the necessary background. The same polemical and philosophical passages are a fascinating glimpse into Schoenberg's mind, and many of the later chapters are valuable in understanding how he thought about chromatic tonality.*
> *In short, one reads it to learn about Schoenberg, not to learn harmony.*
> (Campbell, 2000, personal communication)

> *I have used this book as a suggested reading in my advanced harmony classes. It appeals to the student who has a broad enough conceptual grasp of harmony to be able to recognize and appreciate that harmony can be approached from many different viewpoints, as it is very much an art and less a science. Schenker's "Harmony" is also useful in this regard.*
> (Elliott, 2000, personal communication)

[6] *Praktischer Leitfaden zu Schönbergs Harmonielehre: ein Hilfsbuch Für Lehrer und Schüler* (Vienna: Universal Edition, n.d). Stein's Preface dated March, 1923

[7] This discussion group is one of the several electronic discussion groups maintained by *The College Music Society* (http://www.music.org/), which is a consortium of college, conservatory, university and independent musicians and scholars interested in all disciplines of music.

In summary, we believe the main reason for Schoenberg's method not being adopted as the main textbook in the vast majority of undergraduate harmony courses is that is difficult to extract the fundamental curriculum and method from the text. The difficulty is that these are buried in lengthy philosophical discussions of polemical arguments and criticism of traditional methods.

1.4.3 Computational Implementability

In addition to addressing the problems with traditional methods, as described in Section 1.4.1, Schoenberg's method particularly presents a number of advantages over traditional methods in respect of the computational implementability:

Isochrony

As described earlier (see Figure 1.5 and item(a) in Section 1.4.1), Schoenberg's method does not use time signature and bar separations, and the musical events happen isochronously. This means that there is no need to consider the complex rhythmic influences on the harmonic function in the computational model of the method.

Homophony

Schoenberg's use of pure homophony for most of his method means that there is no need to represent the vast search space of passing-note functions, nor to deal with the complex task of personalising the search in such a space or a student.

Avoidance of Harmonic Analysis

Schoenberg's avoidance of harmonic analysis (see item(b) in Section 1.4.1) implies that, as already mentioned (see item(e) in Section 1.4.1) there is no need to represent a large and heterogeneous corpora of (excerpts from) tonal musical pieces. The task of representing such corpora would be extremely time consuming, with the additional disadvantage of being dependent on the method.

Blank Slate

The starting point of a *blank slate* in Schoenberg's exercises (see Figure 1.5(a)) gives room for the possibility of using a discovery learning framework as described later in Section 1.4.5. Traditional methods require students to master a number of complex musical tasks from the very begining, and therefore are not ammenable to be modelled under the blank slate paradigm.

1.4.4 Cognitive Plausibility

Schoenberg presented, late in his life, a condensed form of his method of teaching tonal harmony (Schoenberg, 1989). This book presents also his final thoughts on tonal harmony, such as his charts of key distance showing how closely or remotely related a key is in respect to a central key. These charts are in close accord with the findings from Krumhansl & Kessler (1982) in respect of empirical judgements of chord-relatedness, as shown in Section 3.4. The matching of empirical results with the theoretical principles underlying Schoenberg's method, highlighted in Krumhansl (1990, pp 46-49), suggests a strong cognitive plausibility of the method, and indicates that further investigation is necessary.

1.4.5 Pedagogical Requirements for Schoenberg's Method

As highlighted in Section 1.3, there are a number of difficulties experienced by beginners who are taught with traditional methods. Using a different set of pedagogical principles can help students to overcome these difficulties. A possible set of pedagogical requirements for Schoenberg's method, which satisfies constraints (A) to (E) in Page 8 and therefore addresses the problems described in section 1.3, is:

1. Students start with a blank stave[8].
2. The harmonisation of a pre-selected melody is not required.
3. Students are asked to select degrees, but are guided in doing so.

[8]Only the (bass and treble) clefs are initially shown.

4. No background knowledge apart from the basics of music notation is required.

5. The approach to teaching harmony should not be too tightly constrained by styles previously widely used.

6. A learner-centred approach is desirable in order to enable students to explore alternative harmonic solutions. However, the sequencing of topics should be kept under the tutor's control.

These requirements seem to indicate the appropriateness of the use of the guided discovery tutoring framework (Elsom-Cook, 1990a) if one aims to produce a computer-based system that might faithfully represent Schoenberg's method. Guided discovery aims to provide students with opportunities to discover things by themselves rather than being taught directly about them. The framework combines human-computer interaction (HCI) and Intelligent Tutoring Systems (ITS) techniques to provide educational environments through which students can explore the particular domain while receiving proper assistance from the (computer-based) tutor. Interactions between student, teacher and the environment are supported within this framework: this is discussed in more detail in Chapters 4 and 5.

1.5 Aims of the Research

We are investigating the possibility of using Schoenberg's harmony teaching method in a computer system and the implications that arise from such usage. The main question we are trying to answer is:

> *Is it possible to design and construct a computer-based learning environment presenting the pedagogy and curriculum of Schoenberg's method while remaining true to its spirit?*

More specifically, the questions we are addressing in this dissertation are:

1. Is it possible to formalise the rules of Schoenberg's harmonic method in such a way that they are amenable for use in a computer-based environment?

2. Is it possible to embody the basic principles of chord construction and connection as specified in Schoenberg's method in such an environment?

3. Can the materials of Schoenberg's method be delivered by a computer-based learning environment so as to explore the full range of activities available in a way appropriate to the method?

4. Is there a satisfactory means by which we can make such formalised materials (see '3' above) potentially accessible to the user?

To address these questions we developed a prototype of a Learning Environment embodying the initial subset of the curriculum and associated principles. The prototype was evaluated by a group of expert musicians and harmony lecturers and the results from the evaluation, described in Chapters 6 and 8, indicate that the embodiment of Schoenberg's pedagogy and curriculum in the prototype of the learning environment was satisfactorily achieved.

1.6 Structure of the Thesis

The structure of the thesis is as follows:

Chapter 1 poses the problem to be addressed and outlines the related questions.

Chapter 2 presents a survey of the applications of computers in music education, with an emphasis on teaching strategies and knowledge represented within these systems.

Chapter 3 discusses the role of theories of learning within the teaching of harmony.

Chapter 4 describes the formalisation of Schoenberg's harmony teaching principles, which guided the design of the interface and of the Learning Environment itself.

Chapter 5 presents the design of the human-computer interface and the influence of the guided discovery tutoring framework.

Chapter 6 describes an evaluation of the usability of the prototype interface carried out with expert musicians.

Chapter 7 describes the design of the Learning Environment, built on top of the interface presented in chapter 5.

Chapter 8 describes an evaluation of the prototype environment run with music teachers.

Chapter 9 closes the dissertation with a general discussion and presents some conclusions.

Appendices contains complementary information such as materials used in the two evaluation studies and transcriptions of the relevant parts of the semi-structured interviews.

Chapter 2

Computers in Music Education

This chapter provides a survey of the application of computers in music teaching. The systems are classified by musical activity rather than by technical approach. The instructional strategies involved and the type of knowledge represented are highlighted.

2.1 Introduction

There have been numerous attempts to use computers in music education. As a result of the highly interdisciplinary nature of the field, these applications use different and sometimes contrasting approaches. This chapter classifies applications by activities involved in musical teaching, and addresses the instructional strategies, if any, involved. The categories considered are computer applications intended to:

- teach fundamentals of music;
- teach musical performance skills;
- perform analysis of music;
- teach musical composition skills.

Applications in which the computer fulfils only an instrumental role such as sequencer and music notation packages will not be covered by this review. Our

focus is on applications in which the student is encouraged to freely explore educational environments and micro-worlds or is guided through an instructional task.

Music education applications use a range of techniques from Computer Assisted Instruction (CAI) to Intelligent Tutoring Systems (ITS)[1] in conjunction with different instructional strategies. Whilst this is a continuum, differences between these approaches at the extremes will be considered here. Contrasting with ITS, CAI systems present a limited teaching strategy, as they have no explicit representation of the knowledge to be taught or ability to reason about it, and cannot differentiate between different students. On the other hand, an ITS basically consists of an instructional environment containing three kinds of knowledge (Burns & Capps, 1988): (i) *expert knowledge* of the domain being taught, that is, the ITS should "know" the subject matter well enough to be able to draw inferences and solve problems in that specific domain; (ii) *student diagnostic knowledge*, meaning that it should be able to understand the student's approach to the knowledge, detect and correct possible misconceptions, and (iii) *curricular knowledge*, in such a way that it should be able to reduce the difference between the expert and the student knowledge by means of specific pedagogical approaches.

In the next section we describe the instructional strategies that have been used in educational software design. In Sections 2.3 to 2.6 we describe applications according to the musical activities involved, and in Section 2.7 we provide a summary of the chapter.

2.2 Instructional Strategies

A widely accepted classification of theories of human learning distinguishes between *connectionist* (or *behaviourist*) and *cognitive* approaches (Child, 1973), and

[1] We will use this term throughout this thesis to refer to the general class of intelligent educational tools. Other terms frequently used by researchers in the Artificial Intelligence and Education (AIEd) area include Intelligent Learning Environments (ILE), Intelligent Computer Assisted Instruction (ICAI), and so on.

it is particularly meaningful in relation to educational software design. While connectionist theories treat learning from the point of view of links between stimulus and response, cognitive theories emphasize the functioning of the brain and how cognitive structures modify the learner's behaviour.

Figure 2.1, slightly adapted from Sorisio (1987), shows the relationship between the most common *Instructional Strategies* that have been used in educational software design and their relationship with the basic classes of the theories of learning.

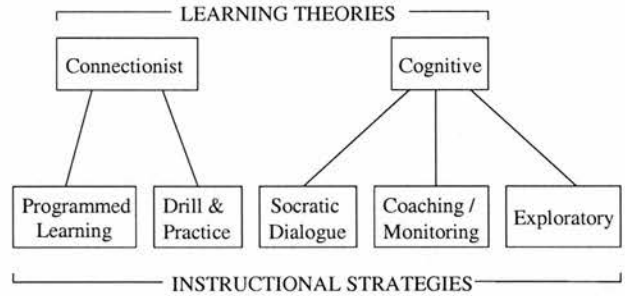


Figure 2.1: The relationship between learning theory classes and the most common instructional strategies found in educational software

Each one of these instructional strategies presents some important features:

- Programmed Learning: based on the work of Skinner (1961b) in *operant conditioning*, forms the basis for CAI. The idea behind programmed learning results in presenting frames with pre-stored material to the student. Responses to some questions should be given by the student, with the system providing comments according to the student's answers, which are simply matched to pre-stored expected responses.

- Drill & Practice: This strategy involves repeating a sequence of activities until the sequence is spontaneous, usually by means of a more interactive CAI to motivate the student.

- Socratic Dialogue: This is a discovery-learning strategy that relies on educational interactions in which the tutor tries to force the recognition and correction of misconceptions.

- Coaching/Monitoring: This is a strategy based on the engagement of the student in a task, while keeping track of the student's activities and giving advice when suboptimal behaviour is identified.

- Exploratory: This discovery-learning strategy encourages the exploration of a domain and usually does not include a direct tutorial component.

2.3 Teaching Fundamentals of Music

Most existing programs related to Music Education have concentrated on activities such as teaching music notation or performing "aural tests" involving recognition and dictation of rhythm patterns, musical intervals, melody patterns, chord qualities and harmonic progressions (Hofstetter, 1988). Computer-based practice allows individual students to practice in less stressful conditions if compared to group-based practice, as research suggests that students may feel less anxious about performing without a human audience (LeBlanc et al., 1997).

The most usual approach to this kind of teaching is the CAI. In fact, this was one of the first uses of computers in education (O'Shea & Self, 1983). The branching programs involved must consider every possible path through the frames being presented to the student. As the number of possible routes can become very large, the preparation of this kind of material normally requires a huge effort. To minimise this effort a template could be used, instead of pre-storing the questions and answers. This technique, named *generative computer assisted learning*, could control – in a restricted sense – the subject and level of difficulty of the next example according to some pre-specified strategy.

Earlier computer-based music instruction applications are reviewed by Gross (1984), and the use of CAI for this kind of teaching is revealed to be of great value, particularly in drill and practice of basic skills. A paradigmatic example of CAI in music is the GUIDO system (Hoffstetter, 1975; Hofstetter, 1981), which was used also to practise and test aural skills. Musical dictation concerning musical intervals, melody, chords, harmony and rhythm are overseen by GUIDO. These activities were accomplished through a four voice synthesiser and a touch sensitive

display, with the student being invited to select an answer that best describes what he thinks he has heard. Based on the student's responses, GUIDO selects the next material to be presented and acts also on the speed of dictation or the time allowed for the answers to be given.

A significant number of commercial music instruction applications such as MiBAC Music Lessons, Music Ace and Practica Musica, most of them for teaching fundamentals of music, are reviewed by the Nackid (1996). While most of these applications use multimedia presentation techniques and MIDI devices extensively, the reviews indicate again the role of computers as highly specialised multiple choice questionnaire administrators, and the use of programmed learning and drill & practice continues to dominate this kind of teaching. However, an aural training system intended as a tool with which to experiment with different instructional strategies for ear training was already developed (Trewin, 1999; Wiggins & Trewin, 2000).

2.4 Teaching of Musical Performance Skills

The activities involved in the teaching of fundamentals of music may be viewed as *supportive* to the teaching of musical performance skills. These activities alone do not significantly improve the performance ability of the students (Swanwick, 1979), and other aural abilities relevant to musical performance should be developed. In this section, we describe some attempts to improve abilities such as "playing by ear" and using aural feedback to correct one's own performance.

The Tunemaster program (Kirshbaum, 1986) addresses the ability of "playing by ear", with the student being invited to play back a melody generated by the system using a touch-tablet. There is no need for previous knowledge of conventional music notation and the student is motivated through the engagement in a computer-based game.

The difficulty that students experience making fine adjustments in their own performances is addressed by Lamb & Buckley (1985) and Yoshinori & Nagaoka (1985). Both approaches use *visual feedback* in the form of a piano-roll graphi-

cal interface, and the difference between them is that the latter also presents a graphical display of expert performances. A similar approach was also used in the Piano Tutor Project (Dannenberg et al., 1990), which is an ITS for teaching the psycho-motor skills of piano playing. Its approach also relies on giving tutorial feedback on the accuracy of the novice's piano performances, but the system is supported by interactive video-disks of a human teacher and a matcher for comparing the student's performance with pre-stored expert performances. Score-following techniques are used as a basis for detecting student errors, and the student model enables instruction to be tailored to the needs of the individual student.

The development and improvement of music performance skills relies on tools with aural and visual feedback as central elements. ITS approaches supported by expert performances and score-following techniques are suitable for helping the improvement of the interpretative abilities of students as in INTERPRET (Baker, 1992), but only within the limited range of previous example pieces. The understanding of the higher level reasoning of real performers could help extend the range of the performance skills beyond pre-stored example pieces, and this was partially addressed in the pianoFORTE system (Smoliar et al., 1995). A model for expressiveness in performances was developed with the help of piano instructors, and this knowledge was encoded in the system. Student's performances on MIDI keyboards are captured and visual feedback concerning expressive performance aspects such as tempo, synchronisation, dynamics and articulation are presented to the student on the original score.

2.5 Computers in Music Analysis

Music analysis deals with the determination of the constituent elements of a musical structure and the investigation of the functions of these elements within that structure (Bent, 1987). As a result of the relationship of music analysis theories with music aesthetics and compositional theories, different views of the nature of music or the role of the human intellect with regard to music are embedded in

them. This relationship explains why some music theories are mutually exclusive with other theories.

In this section we give a summary of the use of computers in music analysis as a tool for teaching or as a procedure for investigation. The applications reviewed have been used to test music theories (Baker, 1989a,b; Robbie, 1994), to check the authorship of musical pieces (Gross, 1975), or even to identify where in musical pieces established rules were observed or broken (Blombach, 1981). Computers in music analysis are typically used for event counting, sorting, pattern recognition and statistical analysis (Alphonce, 1980). All these programs recognise occurrences of pitches, notes values, intervals and also patterns and combinations of the previous musical elements.

One of the first attempts to use computers to assist in music analysis was made by Gross (1975). She developed a set of routines for melodic and vertical pattern scanning, thematic tracing, harmonic analysis, set theory and for keeping a cumulative count of results. Representative pieces from different musical styles composed by Bach, Haydn, Chopin and Dallapiccola were analysed, and the results were, for the most part, accurate and provided useful quantitative data.

A less generic music analysis tool intended to test the validity of music theory textbook statements about Bach chorales was developed by Blombach (1981). With this tool, it is possible to determine the range of each of the four voices, the number of times pairs of voices cross, the occurrences of parallel perfect fifths and to examine resolutions of tritones. Students find these exercises especially satisfying if they prove the textbook author's discussion inaccurate, imprecise or incomplete (Blombach, 1981).

Some aspects of the theory for tonal music analysis proposed by Heinrich Schenker (1867-1935) were implemented by Smoliar (1971, 1980) as a framework. This theory is centred on a principle of reduction (Cook, 1987; Monelle, 1992; Sloboda, 1985), in which a musical piece can be viewed as a large-scale embellishment of a simple underlying harmonic structure. Smoliar's framework enables a music theorist interactively to formulate an analysis through a compound of Schenkerian transformations.

Other theory-oriented attempts (Baker, 1989a,b; Robbie, 1994) involving knowledge-based systems have implemented aspects of the Generative Theory for Tonal Music (GTTM), one of the most influential theories of tonal musical structure (Lerdahl & Jackendoff, 1983). This theory is a step toward the understanding of musical cognition, improving on Schenker from within the paradigm of generative transformational grammar. But research should be carried out to achieve an even more complete formalisation of the principles by which the listener assigns structures to a musical piece. Some ambiguity arises if we notice the different ways that a piece of music is heard by different people, and this is taken into account by the transformational rules of GTTM. The system proposed by Robbie aims to interactively derive the groupings from a tonal piece according to the grouping component of GTTM, while Baker deals also with the time-span component.

Probabilistic and knowledge-representation based techniques supported by established music theories are the dominant approaches to music analysis. The next section presents a greater diversity of approaches to the task of music composition, as a result of this domain's more open-ended nature.

2.6 Computers in Music Composition

In this section, we consider applications of computers in music composition ranging from interactive educational games to specialized ITS. Teaching strategies from simple concept presentation to more exploratory approaches exist, and potential users range from novices to experienced composers.

Music Logo (Bamberger, 1974) is a representative example of the use of an interactive educational game in music composition. Its aim is to apply the ideas of the Logo language to music, where the student learns through modelling – building and testing models. Experiments involving manipulation of musically meaningful elements support Bamberger's claims about the benefits on the construction and improvement of the pupil's musical knowledge through play (Bamberger, 1991). Some other open-ended microworlds applying Logo techniques to music composition have been built, such as that of Gargarian (1993), LOCO

(Desain & Honing, 1986) and Object LOGO (Greenberg, 1988).

Other authors present interface-oriented approaches, such as a musical game involving transformations of sketched freehand curves on staves (Lamb, 1982). Operations such as time or amplitude stretching, shrinking or transposition could be applied to excerpts of the sketched melody producing interesting results with arguable educational value.

Styles as specific as sixteenth century two-voice counterpoint (Newcomb, 1985) and eighteenth century four-voice chorales (Thomas, 1985) have been addressed through ITSs which take advantage of the relatively well-known harmonisation rules for these focused domains. Other work is based on multiple instructional strategies for teaching basic theoretical concepts and how to use them to recognize, play and compose harmonic materials (Sorisio, 1987; Tobias, 1988).

ITS approaches based on cognitive tonal music theories for melody (Narmour, 1990) or harmony (Balzano, 1980) can also be identified in MOTIVE (Smith & Holland, 1994; Smith, 1995) and Harmony Space (Holland, 1989, 1994). MOTIVE is a constraint-based learning tool intended to be used by beginners in exploring the composition of melodies through an iconic interface based on the traditional music notation. Harmony Space is a highly interactive tool for learning about tonal harmony that is based on a representation of the harmonic relationships on a bidimensional matrix. Besides the fact that the interface is not based on the traditional music notation, the evaluation of the system indicates that with some initial guidance novices could easily navigate and produce musically interesting accompaniments. This exploratory tool gave rise to MC (Holland & Elsom-Cook, 1990), a more general framework intended to teach students how to compose tonal chord sequences whilst being supported by a variety of guidance strategies.

Cook (1994) fosters high level compositional skills through reflection, modelling the teacher and the learner in two different roles. He presents a plausible cognitive model of how composers perceive tonality while composing. The aim of Cook's system is to engage a learner in some goal-directed, problem seeking activity in music composition and to foster the student's own ability to be reflective about the learning. In more recent work, a Knowledge Mentoring framework

was used to investigate the teacher-learner interactions in the domain of musical composition, providing a taxonomy of the pedagogical goals involved in a mentoring-like way of teaching (Cook, 1998b). A teaching agent based on this framework was developed and evaluated, and the results indicate potential for the design of ITS for other domains, such as the teaching of social science, that rely on creative, metacognitive and critical thinking (Cook, 1998a)

The harmony teaching learning environment prototype described in this research (see Chapters 5 and 7) was designed to enable the *simultaneous* use of the coaching/monitoring and exploratory instructional strategies (see Figure 2.1): at the same time that students are allowed to freely explore acceptable harmonic solutions to problems, they are being given feedback on what they are doing, and guided through the lessons. A well defined curriculum built on top of an exploratory environment distinguishes the environment from previous work described in this section. The environment was built aiming to accommodate the main pedagogical principles of Schoenberg's method of teaching harmony and to collect empirical evidence to help answering the research questions presented in Section 1.5 (see Chapters 6 and 8). The full embodiment of Schoenberg's method will require modifications/expansions to be made in the environment, as suggested in Section 9.4.

Musical composition is not a well-defined task, and its goal could be defined as "to compose something interesting" (Levitt, 1985). As a result of such an open-ended domain, techniques ranging from interactive games without any kind of guidance to highly focused ITSs with multiple teaching strategies to support the specific needs of the students can be identified.

2.7 Summary

This chapter has provided a survey of application of computers in music education, with a focus on applications in which the student is encouraged to freely explore educational environments and micro-worlds or is guided through an instructional task. Table 2.1 relates the reviewed systems with their encoded knowl-

edge and instructional strategies. For simple musical activities such as teaching the fundamentals of music, the programmed learning approach has proved to be appropriate as most of the time these activities involves only comparing the student's answer with pre-stored templates. For the activities involved in music composition and musical performance, the dominant technique is based on cognitive theories of learning. The next chapter presents an overview of the theories of human learning, and identifies the one in which this research is based on.

System	*Musical Task*	*Instructional Strategy*	*Knowledge*	*Comments*
GUIDO (Hofstetter, 1988)	Music theory Ear training	Programmed Learning Drill & Practice	-	aural training and test system
MiBAC Lessons (Nackid, 1996)	Music theory Ear training	Programmed Learning Drill & Practice	-	Well-designed package for musicians
Music Ace (Nackid, 1996)	Music theory Ear training	Programmed Learning Drill & Practice	-	Easy lessons for young musicians
Practica Musica (Nackid, 1996)	Music theory Ear training	Programmed Learning Drill & Practice	-	Comprehensive music literacy program
Tune Master (Kirshbaum, 1986)	Performance Skills	Exploratory	-	Teach playing by ear using a touch-tablet
Lamb & Buckley (1985)	Performance Skills	Drill & Practice	-	Visual feedback of student performance
Yoshinori & Nagaoka (1985)	Performance Skills	Drill & Practice	-	Graphical display of expert performances
Piano Tutor (Dannenberg et al., 1990)	Performance Skills	Drill & Practice Coaching/Monitoring	User model Domain Curricular	Score following; Expert performance

Table 2.1: Some music education applications and their represented knowledge and instructional strategies

System	*Musical Task*	*Instructional Strategy*	*Knowledge*	*Comments*
INTERPRET (Baker, 1992)	Expressive performance	Socratic dialogue Coaching/Monitoring	User model Domain	Performance editing of analised melodies
pianoFORTE (Smoliar et al., 1995)	Expressive performance	Drill & Practice Coaching/Monitoring	User model Domain	Visual feedback of student mistakes
(Gross, 1975)	Analysis	-	Domain	Check authorship
(Blombach, 1981)	Analysis	-	Domain	Test theory
(Baker, 1989a,b)	Analysis	-	Domain	Test theory
(Robbie, 1994)	Analysis	-	Domain	Test theory
Music Logo (Bamberger, 1974)	Composition	Exploratory	-	Logo microworld
LOCO (Desain & Honing, 1986)	Composition	Exploratory	-	Logo microworld
Object LOGO (Greenberg, 1988)	Composition	Exploratory	-	Logo microworld
(Gargarian, 1993)	Composition	Exploratory	-	Logo microworld
(Lamb, 1982)	Composition	Exploratory	-	Free-hand curve manipulation game
LASSO (Newcomb, 1985)	Composition	Programmed Learning Socratic Dialogue	Domain	Sixteenth century 2-voice counterpoint

Table 2.1: Some music education applications (continued)

System	*Musical Task*	*Instructional Strategy*	*Knowledge*	*Comments*
VIVACE (Thomas, 1985)	Harmony	-	Domain	Eighteenth-century 4-voice chorale
THE MUSES (Sorisio, 1987)	Harmony	Multiple strategies	User model Domain Curricular	Based on a harmony expert and a tutoring expert modules
Harmony ITS (Tobias, 1988)	Harmony	Multiple strategies	User model Domain Curricular	Constraint Logic used to represent the domain
MOTIVE (Smith & Holland, 1994)	Melody composition	Exploratory	Domain	Constraint-based tool focusing Narmour's theory
Harmony Space (Holland, 1989)	Harmony	Exploratory	Domain	Interactive tool based on tonal harmony theories
MC (Holland & Elsom-Cook, 1990)	Composition	Exploratory	Domain	Cognitive support framework
(Cook, 1998a,b)	Composition	Socratic dialogue Exploratory	User model Domain	Foster skills through reflection

Table 2.1: Some music education applications (continued)

Chapter 3

Theories of Learning and Schoenberg's Harmony Teaching

The field of Artificial Intelligence and Education (AIEd) was born when AI technology was used within an instructional setting. The earliest paradigmatic example is the SOPHIE tutoring system for electronic troubleshooting (Brown et al., 1982), that embedded most current AIEd concepts such as the student model and the expert module. In its earliest years, the main goal of AIEd researchers was to successfully implement instructional systems. As the field rapidly progressed, it became clear that it would be impossible to implement systems that take into account all possible factors such as topics and student populations. As Ohlsson (1991) proposed, "the real goal of AI&Ed research is to develop a theory of learning under instruction" (Ohlsson, 1991, p. 5).

Given the fundamental role of the theories of learning within AIEd, in this chapter we present an overview of the most relevant learning theories, organised as in Chapter 2: the behaviourism and the cognitivism. As a result of a large number of theories having overlapping principles there is no agreement on how to classify them, and very little agreement for the nomenclature used. The classification made here takes into account common principles from an educational perspective, and the reader should be aware that other authors might provide a different classification depending on the perspective being used.

3.1 Introduction

Different learning theories have been used in the teaching of various sorts of learning, ranging from the acquisition of knowledge to the mastery of a particular skill (Phillips & Soltis, 1985). A unified theory of learning has not yet been achieved because of the existing wide diversity of types of learning, each one demanding different approaches. The teaching strategy involved in the learning of foreign words, for instance, seems not to be appropriate for the learning of chess or of how to solve a differential equation. In the former case an educator would induce rote memorisation while in the latter case a more cognitivist strategy is more likely to be used.

It is not the aim of this chapter to present a review of all existing learning theories, but to provide and an overview of the main principles of the most influential learning theories and to identify which of these principles are found in Schoenberg's approach to the teaching of harmony. The interested reader should refer to comprehensive reviews of the learning theories such as the ones presented in Sahakian (1970) or Bower & Hilgard (1981).

This next two sections introduce the main principles of the most influential learning theories, which are classified, as in Chapter 2, according to the following two categories:

- Behaviourism (or connectionism);
- Cognitivism

3.2 Behaviourism

Behaviourism is a theory of learning that describes animal and human learning as a process of acquisition of new behaviours (Phillips & Soltis, 1985). It is centred on the belief that learning is a process of expanding the learner's *behavioural repertoire*, and discounts mental activities. The main assumption is that learning occurs because, like other animals, we are "biologically wired" so that behaviour

that is reinforced is more likely to recur. Behaviourism proposes two types of conditioning:

Classical conditioning occurs when a response arises from a stimulus. An example is the experiment conducted at the beginning of the century by the Russian physiologist Ivan Pavlov, in which he was able to induce the salivation in dogs by means of conditioned stimulus (Pavlov, 1966).

Operant conditioning is a feedback system based on reinforcement for 'right' responses to a given stimulus, in such a way that the same response to the stimulus is more likely to happen in the future. Skinner (1961a) used this technique to "shape the behaviour" of pigeons via reinforcement in an experiment where he managed to 'teach' them to dance.

One remarkable application of behaviourism on instruction is *Programmed Learning*, where the subject matter is split into *frames*, which are followed by a question. The use of branching, where the student's answer can define what comes next, enables the designer a somehow limited control the flow of instruction. Reinforcement of the learning process is achieved through a right answer that is the reward itself. Computer Assisted Instruction (CAI) is the computerised form of Programmed Learning that can be found in most "auto-instructional" software packages available. Educators agree that in most cases CAI cannot completely substitute an active classroom teacher.

Behaviourism seems to be an incomplete theory as it oversimplifies human behaviour, by not taking into account the fact that several activities which we face daily demand the manipulation of our own *mental maps* – or internal representations for our knowledge – that allow us to behave correctly. Simple experiments (Phillips & Soltis, 1985) show that laboratory rats seem to create a sort of mental map for mazes, in such a way that they are able to guide themselves even when the disposition of passageways of the maze is slightly altered.

3.3 Cognitivism

Cognitivism, in contrast to behaviourism, emphasizes the functioning of the brain and how cognitive structures modify the learner's behaviour. The focus is on "how" to learn, rather than "what" to learn.

3.3.1 Jean Piaget

Jean Piaget's (1977) development theory is based on the idea that children builds *mental maps* – or cognitive structures – of networked concepts for understanding and reacting to physical experiences within their environments. This cognitive structure becomes more and more sophisticated with development, moving from innate reflexes to complex mental activities. Piaget's theory proposes four developmental stages:

Sensorimotor where the child, from birth to two years old, builds concepts about reality through physical interaction with the environment;

Preoperational where the child, from two to seven years old, is not yet able to create abstract concepts and needs concrete physical situations;

Concrete operational where children, from seven to eleven years old, start to develop abstract concepts, creating logical structures that explain their physical experiences;

Formal operations stage is the stage where the child's cognitive structures, from eleven to fifteen years old, are similar to those which an adult presents, and which include conceptual reasoning;

The core idea is that the learning occurs while we are interacting with and adapting to the environment. Piaget identified in this adaptation the following processes:

Assimilation is the process of association of new events with our current knowledge;

Accommodation corresponds to the process of adapting our mental maps to the new information.

Even though nowadays Piaget's ideas are debatable, it is acknowledged that his theory had a strong influence on modern developmental psychologists (Boden, 1979). Constructivism is a well-known theory of learning based on Piaget's ideas, ans relies on an active participation of students in problem-solving and on their critical thinking regarding the learning activities (Fosnot, 1996). The role of the teacher is as a facilitator in charge of helping the students to construct their conceptualisations and solution to problems. The main assumption is that students construct and reconstruct their knowledge while applying their previous knowledge and experience to a novel situation, and that the learning is best achieved when they actively construct their own understanding. Through their experiences students can construct their own understanding of the world by means of developing or improving their individual mental models. From this point of view, learning is the process of adjusting our mental models to new situations (Brooks & Brooks, 1999).

Among the different types of constructivist theories that arose from Piaget's work we can highlight: the *social* constructivism, which supports a discovery model of learning with an emphasis of the influences of cultural and social contexts (Vygotsky, 1977); the *cognitive* constructivism, which is centred on the main belief that we continually build upon our knowledge also through a reasoned integration of our internal contradictions (Bruner, 1986); and the *radical* construtivism, which advocates that the individual's interpretation of the reality is unique and cannot be shared (von Glaserfeld, 1995).

3.3.2 Information Processing

The Information Processing Theory attempts to explain how individuals perceive, organise and retrieve information by means of their cognitive process, and how these mental structures affect behaviour. The aim of the theory is to describe the goal-directed aspects of human behaviour, and the adjustment of concepts of

the world we make as a result of feedback from our actions. The "test-operate-test-exit" principle, also called the TOTE unit, was proposed by Miller et al. (1960) and is central to this theory. Figure 3.1 depicts its feedback mechanism, where we continually check if the goal was achieved (the *Test Goal* box) or not. In the former case the loop can be exited (the *Exit* box), otherwise an action is requested (the *Operate* box).

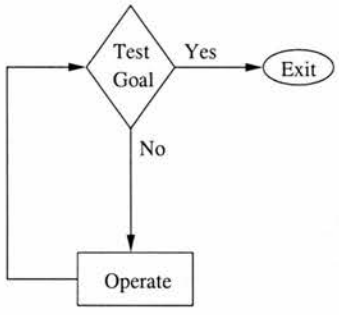


Figure 3.1: The test-operate-test-exit principle

The theory considers that information is stored in and processed by different types of memory:

short term memory or working memory, which is where information is stored for a short period of time (usually up to 20 seconds). The information is grouped by meaning, into discrete units called *chunks*. Five to nine chunks can reside at the same time at the working memory (Miller, 1956);

long term Memory which is where information is stored permanently, being the capacity apparently limitless. Different kinds of knowledge are stored in different parts within the long term memory:

- **Declarative memory**, which is where the factual or conceptual knowledge is stored;
- **Procedural memory**, which is where the *production rules*, or a set of condition-action rules, associated to a particular task are stored.

sensory memory or "iconic" memory, which is originated during the process of transduction of the information (sound, light, taste, smell, etc.) presented

to our sensory receptor cells into the electrical impulses that the brain can understand. The information lasts for a very short period of time (e.g. 1/2 second for vision);

Information Processing Theory is one of the most influential explanations of human cognition, and a number of recent learning theories is based on it, from which only a few of them are described below:

Repair Theory attempts to explain how procedural skills are learned with a focus on student's 'buggy" procedures. The theory assumes that students use *repair strategies* to overcome impasses that arise when solving procedural tasks. These strategies might lead to correct outcomes or to incorrect results, in which case a buggy repair procedure can be identified. Brown & VanLehn (1980) used these ideas to identify the most common buggy procedures in the domain of learning subtraction, and to found ways to prevent them;

Modularity Theory suggests a modular organisation for the mind. Fodor (1989) proposed the idea of a mind made upon special-purpose independent modules, which is in contrast with the position that the mind is a general-purpose problem solver (Newell & Simon, 1972). According to Fodor (1989), a cognitive system presents three levels: the *transducer* level, in which information from the external environment is transformed into formats each special-purpose module can handle; the *input systems* level, which performs basic recognition and description functions, and outputs data in a common format to the next level; and the *cognitive functions* level, in which a domain-general processing takes place.

ACT-R Theory is a general theory of cognition (Anderson & Lebiere, 1993) that suggests that learning is achieved in three stages: the *interpretative* stage, in which the declarative knowledge involved is understood; the *compiled* stage, in which the task is proceduralised; and the *strengthening* stage, in which a fine-tuning of these procedures takes place. The ACT framework

has evolved since the first model of a semantic memory was proposed by Anderson & Bower (1973), and took various forms before reaching its maturity (Anderson, 1976, 1983). It has been applied succesfully to make accurate predictions about a number of behavioural phenomena ranging from cognitive arithmetic (Lebiere, 1998) to metaphor comprehension (Budiu & Anderson, 2000), and models can be potentially built for new domains taking knowledge representation and parametrization from existing domains.

3.4 Cognitive Fundamentals of Schoenberg's Harmony Teaching Method

Schoenberg presented, late in his life, the fundamentals of his original method of teaching harmony (Schoenberg, 1989), also with his final thoughts on tonal harmony. Taking the principle of *monotonality* as a starting point, Schoenberg developed his *charts of key distance* and the concept of *regions*. The principle states that there is only one tonality in a piece, and every segment, originally considered by former theorists as modulation, is just a region within a tonality, which Schoenberg classifies as: *close and direct*; *indirect but close*; *indirect*; *indirect and remote*; and *distant*. Figure 3.2 shows the chart of distance for the C-major key[1], and Figure 3.3 shows the chart of distance for the A-minor key, where capital letters stand for major keys, and lowercase letters stand for minor keys.

These charts were found in Krumhansl (1990, pp 46-49) as subsets of the *scaling solution*, a multidimensional representation (see Krumhansl & Kessler (1982)) for empirical judgments of chord-relatedness, centered around a key that is in control of the tonality. This empirical result indicates a strong cognitive plausibility for Schoenberg's method, and gives support to the research described in this thesis.

[1]The concept of major and minor key signatures is introduced in Section 4.1.

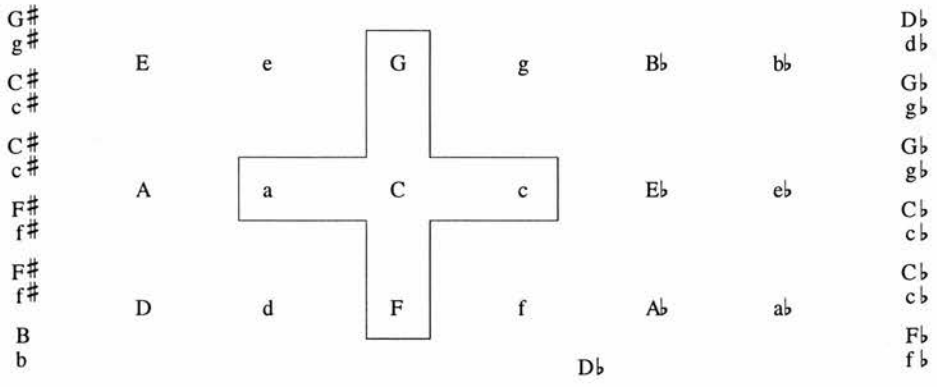


Figure 3.2: Chart of key distance for the C-major key

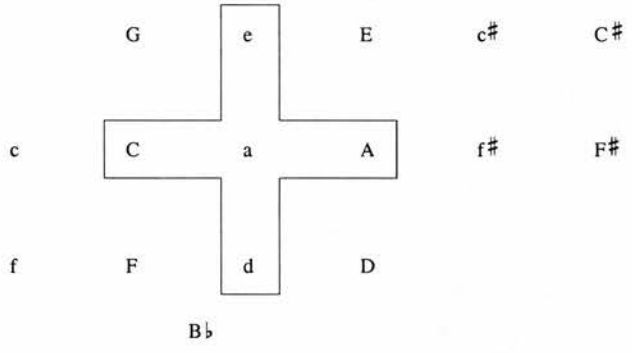


Figure 3.3: Chart of key distance for the A-minor key

3.5 Summary

This chapter provided an overview of the most relevant theories of learning classified as in Chapter 2: behaviourism and cognitivism. The main principles for some of the existing theories were introduced, and the cognitive fundamentals of Schoenberg's method of teaching harmony were introduced. The next chapter details the principles of Schoenberg's harmony teaching method.

Chapter 4

Schoenberg's Harmony Teaching Principles

This chapter introduces the diatonic scales and the main Schoenberg's ideas for the harmony teaching. A formalisation to the part of Schoenberg's method of teaching harmony incorporated into the learning environment designed in Chapter 7 is then introduced.

4.1 The Diatonic Scale

Tonal music is based on the *diatonic scale*, which can be on the *major* or *minor* mode. This section introduces the diatonic major and minor scales, which form part of the assumed background information for beginners starting to learn through Schoenberg's method.

4.1.1 The Diatonic Major Scale

The diatonic major scale, also known as the *major scale*, is made up of seven notes that follow the same distribution of tones and semitones (or whole-tones and half-tones) as instantiated in Figure 4.1 for the C-major scale.

The notes that make the C-major diatonic scale correspond to the white keys of a musical keyboard. The pattern of tones and semitones between adjacent notes

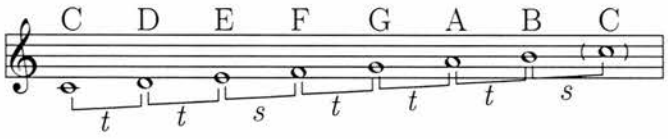


Figure 4.1: C-major diatonic scale

of the scale can be observed on the musical keyboard layout shown in Figure 4.2.

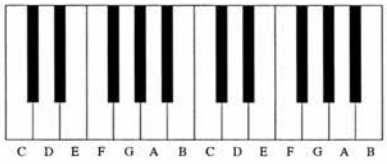


Figure 4.2: The layout of the keys on a musical keyboard

The seven notes of the diatonic scale are referred to as *degrees* of the scale, and are usually numbered using Arabic numerals *1* to *7* with a caret symbol (ˆ) on top of it (e.g. $\hat{4}$). The first numeral $\hat{1}$ is associated with the *tonic* or *key-note* taken as the starting point for building the scale. Figure 4.3 depicts the distribution of degrees for the C-major scale while Table 4.1 shows the names by which these degrees are known.

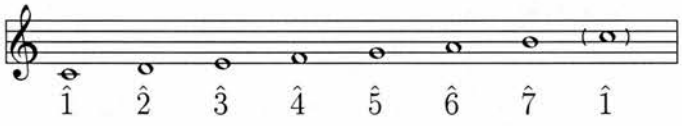


Figure 4.3: Degrees of the C-major scale

Degree	Name
$\hat{1}$	*Tonic*
$\hat{2}$	*Supertonic*
$\hat{3}$	*Mediant*
$\hat{4}$	*Subdominant*
$\hat{5}$	*Dominant*
$\hat{6}$	*Submediant*
$\hat{7}$	*Leading Tone*

Table 4.1: Degrees of the diatonic major scale

The term *interval* is used to designate the distance between two degrees of a particular scale. The name of an interval is found by counting the lines and spaces between the notes, up to and including the notes themselves. Figure 4.4 shows the intervals of the degrees of the C-major diatonic scale in respect to its tonic.

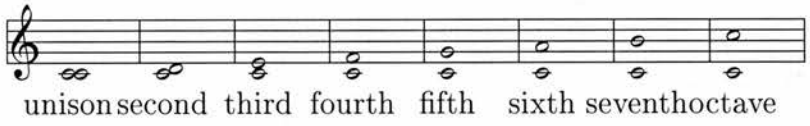


Figure 4.4: The diatonic intervals

Different *key signatures* are needed to indicate the accidentals necessary to form diatonic major scales presenting the same distribution of tones and semitones as in Figure 4.1, independently of the initial tone being considered. Figure 4.5 shows all key signatures for major *keys*.

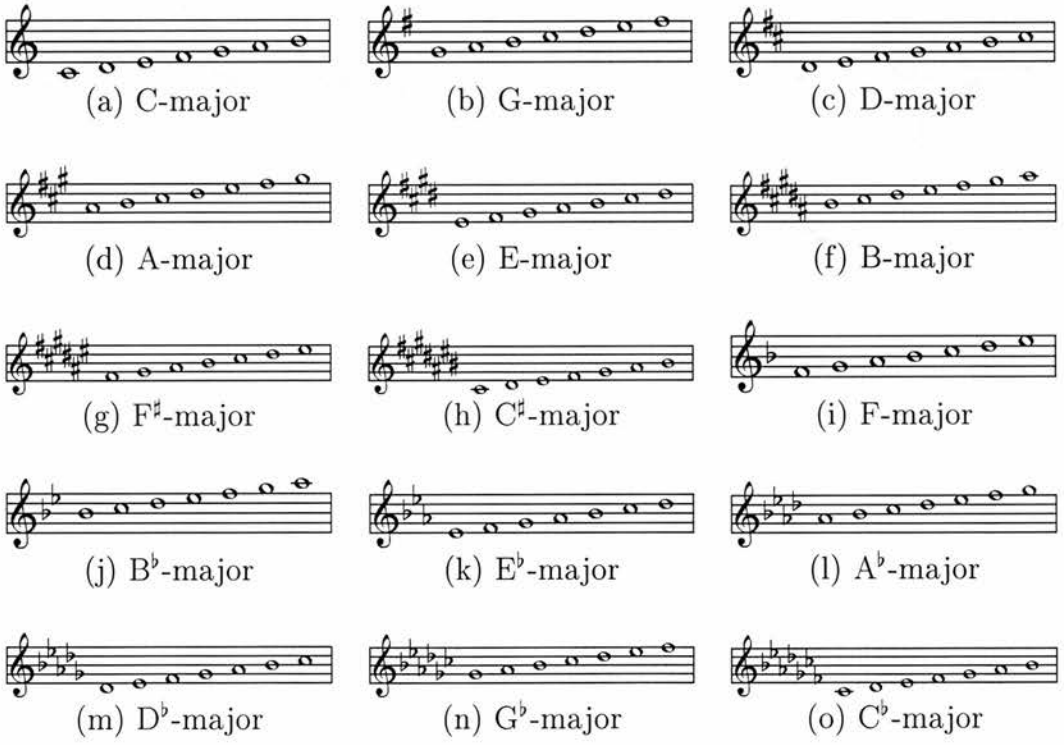


Figure 4.5: The diatonic major scales

4.1.2 The Diatonic Minor Scale

The diatonic minor scale is made up of seven notes that follow the distribution of tones and semitones shown in Figure 4.6 for the A-minor scale[1]. As before, different *key signatures* are needed to indicate the accidentals necessary to form diatonic minor scales on different keys, as shown in Figure 4.7.

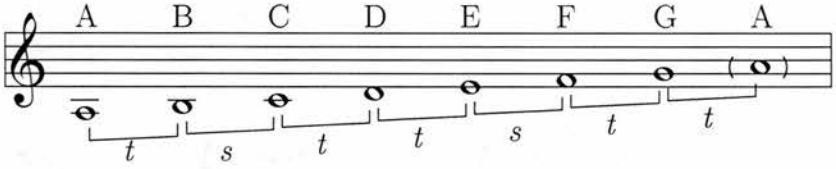


Figure 4.6: A-minor diatonic scale

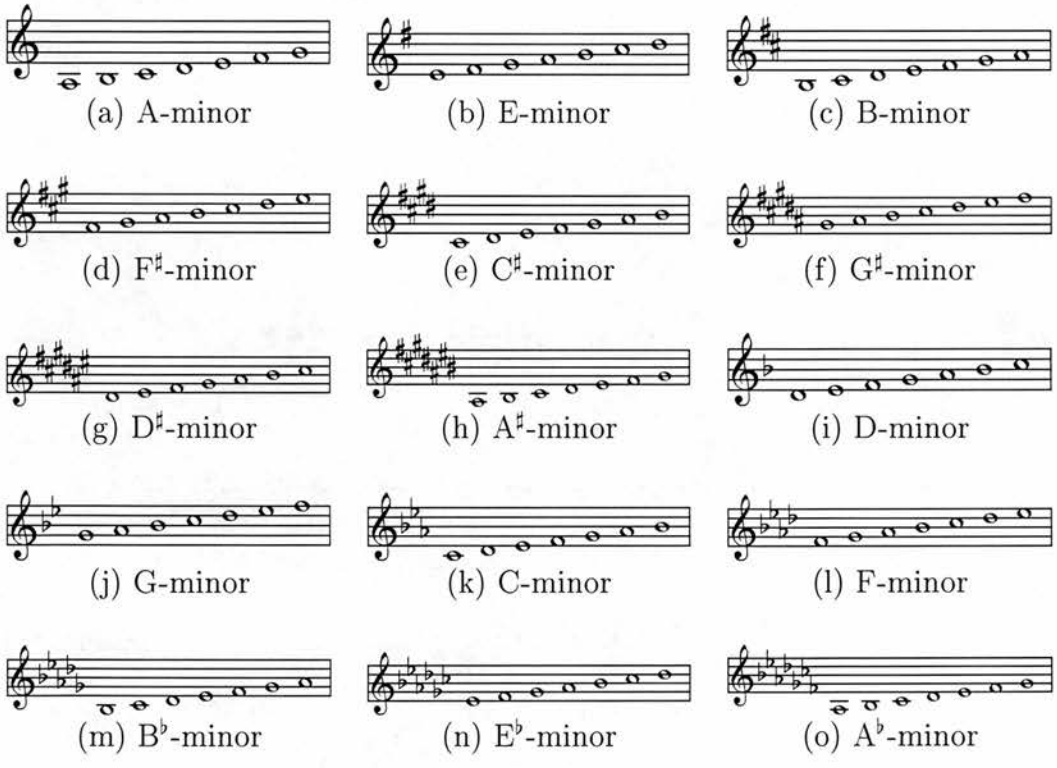


Figure 4.7: The diatonic minor scales

[1]The minor mode is more complex than the major mode, and there are several scales used to illustrate different aspects of it. The scale in Figure 4.6 is the *natural* minor scale.

Although the minor mode does not take part in the formalisation of the part of Schoenberg's method (see Section 4.2) incorporated in the prototype learning environment designed in Chapter 7, its concept is needed when one tries to understand the principles that inform Schoenberg's harmony teaching presented in Section 3.4.

The next section gives the formalisation of the part of Schoenberg's method which was incorporated in the learning environment designed in chapter 7.

4.2 Schoenberg's Harmony Teaching Principles

This section describes Schoenberg's harmony teaching principles in the same order as described in his method. The same notation as in Schoenberg (1990) is used to represent triads or chords, that is, Roman capital numerals. However, the following chapters use the more common notation for chords that associates Roman capital numerals with major chords (I, IV and V for the major mode scale), using Roman lower case numerals for the other chords.

4.2.1 The Diatonic Triads

A chord is a combination of two or more notes played simultaneously. One of the simplest chords is a *triad*, that is made up of three notes by means of superposing two thirds. Figure 4.8 presents the diatonic triads that correspond to the seven triads that are built over the degrees of the major scale.

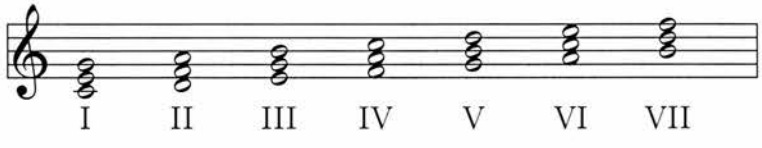


Figure 4.8: The diatonic triads in C-major

The structure of these triads could be described using only the interval of a major third, where the distance between the notes is equal to 4 semitones, and

the interval of a minor third, where the distance between the notes is equal to 3 semitones. The triads based on the degrees of the major scale are classified as:

- *major triads*: based on the degrees I, IV and V. They are formed by means of a *major third* interval below a *minor third*, presenting a perfect fifth interval between the extreme notes;

- *minor triads*: found on the degrees II, III and VI. They are formed by means of a *minor third* interval below a *major third*, also presenting a perfect fifth interval between the extreme notes;

- *diminished triads*: found on the degree VII. It is formed by means of *two superposed minor third* intervals, presenting a diminished fifth interval between the extreme notes.

Except for the triad on the VIIth degree, the triads are also known by the names of the degrees of the scale, as shown on the Table of Figure 4.9:

Triad	**Name**	**Type**
I	*Tonic*	major
II	*Supertonic*	minor
III	*Mediant*	minor
IV	*Subdominant*	major
V	*Dominant*	major
VI	*Submediant*	minor
VII	*Diminished*	diminished

Figure 4.9: Triad names and types

The next section will show how the notes of chords can be split into melodies, or *voices*, according to the concept of four-part writing adopted by most composers from the eighteenth and nineteenth centuries.

4.2.2 Spacing the Chords

One common convention is to use four-part writing, using the principal types of human voice: soprano, alto, tenor and bass. The range of each one of these voices is shown on Figure 4.10, and it should be noted that the higher and lower registers could be used only in passing because they demand more effort from the singer and cause more fatigue.

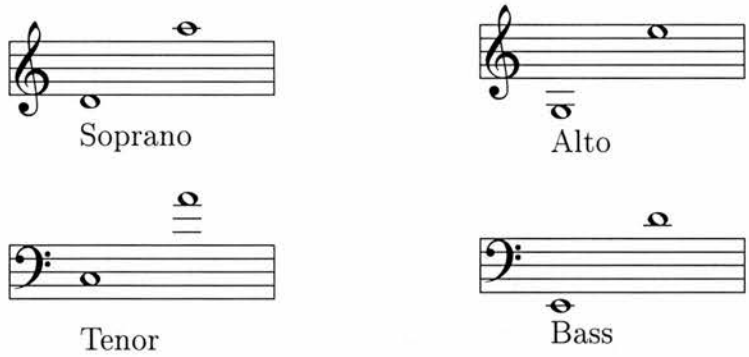


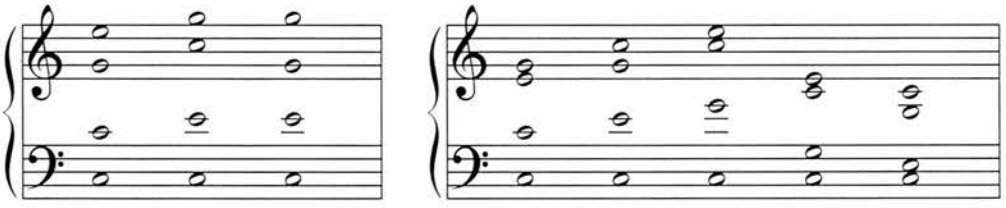
Figure 4.10: The range of the four voices

The voices could be spaced on two ways:

- *Close* [2] *Position*: no other chord tone can be inserted between two adjacent voices of the upper three voices.
- *Open Position*: if one or more voices can be inserted between two adjacent voices of the upper three voices.

As we have adopted four-part writing and the triads use only three distinct degrees, one of these degrees must appear twice, perhaps separated by one or more octaves. This can be seen in each of the examples of open and close position of chords shown on Figure 4.11. This figure also presents a musical notation convention we will follow in this work that usually the soprano and alto voices are presented on the staff with the treble clef, and the tenor and bass voices are presented on the staff with the bass clef.

[2]This is the expression adopted not only in Schoenberg's method, but also in most harmony books.



Open Position Chords Close Position Chords

Figure 4.11: Examples of chord positions

Some basic heuristics which are likely to produce a chord that sounds correct should be followed:

- *no* two adjacent *voices* (of the upper three) should be *separated by more than an octave*
- there is no restriction for the spacing between the bass and tenor
- the order of preference for *doubling degrees* is: preferably the root, then the fifth, and in some special cases the third

The next section deals with the principles that should be observed when connecting triads.

4.2.3 Connection of Diatonic Primary and Secondary Triads

On this section we are interested in connecting one triad with another, restricting this connection to only the ones that present one or more common tones between them. Table 4.2 presents the triads that have common tones with each other. It should be noted that every triad on a particular degree has one or more common tones with every other triad, except the ones whose root is directly before or after this particular degree.

It should be noted that the triads whose roots are spaced by a fifth or fourth only present one common tone (e.g. I, IV, V; II, V, VI; III, VII, I; etc...), while those with roots spaced by a third or a sixth present two common tones (e.g. I, III, VI; II, IV, VII; III, V, I). The table shown on Table 4.3 presents, in a more appropriate format, the same information of the table on Table 4.2:

I	.	III	IV	V	VI	.
.	**II**	.	IV	V	VI	VII
I	.	**III**	.	V	VI	VII
I	II	.	**IV**	.	VI	VII
I	II	III	.	**V**	.	VII
I	II	III	IV	.	**VI**	.
.	II	III	IV	V	.	**VII**

Table 4.2: Triads that present common tones

Degree	has common tones with			
I	III	IV	V	VI
II	IV	V	VI	(VII)
III	I	V	VI	(VII)
IV	I	II	VI	(VII)
V	I	II	III	(VII)
VI	I	II	III	IV
VII	II	III	IV	V

Table 4.3: Triads that present common tones

According to the simplifications we will follow closely in the exercises and examples of this section and that will be later on removed, we should:

- only use triads that have one or more common tones;
- exclusively double the octave in the initial chord;
- only use as the bass line the fundamental degree;
- ignore the VII degree and its connection with other degrees.

On making these connections some general directions should be observed in order to make the connections as smooth as possible:

- the voices should follow the *'law of the shortest way'*:

  - sustain the common tones as a harmonic link (each voice should move only when it must)
  - each voice should take the smallest step which will allow the other voices to take small steps

- avoid crossing of voices
- choose between close or open position of the chords

In developing these exercises, the pupil should first decide between the close or open position of the first triad with octave, third or fifth on the top. Then the following questions should be answered, in the order given, to avoid mistakes while *spacing the chords*:

1. Which tone goes in the bass? - The root, according the simplification adopted
2. Which tone in the soprano?
3. What is missing? (Space the missing tones according the choice of position - close or open)

Similarly, while *connecting the chords* the questions below should be carefully answered, taking into account the simplifications and directions above, in order to create properly connected triads:

1. Which tone is the root? - it should go to the bass, according to the simplifications adopted;
2. Which are the common tones? - Sustain them;
3. Which tones are still missing?

Figure 4.12 shows some examples of spacing and connecting two triads, taking into account the simplifications and directions adopted so far. The first bar shows connection of an open position triad on the I^{st} degree, having a third on top, with a triad on the III^{rd} degree. The answers to the questions of connecting these chords should be:

1. Which tone is the root? e, that should go to the bass;
2. Which are the common tones? e and g. Therefore the e is held over the soprano and the g is held over the alto;
3. Which tones are still missing? b (the tenor goes from c to b).

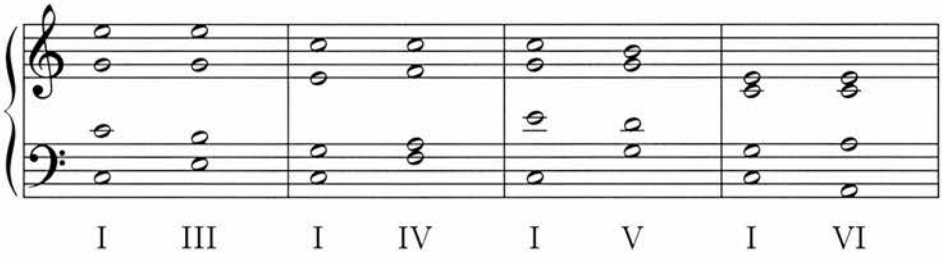


Figure 4.12: Examples of connection of triads

The pupil, at this stage, should practice the different ways of connecting each of the other degrees using the simplifications and directions given. Some confidence on how to achieve appropriate chord connections should be acquired by the student, as the next activity demanded by Schoenberg's method involves the connection of chords in short phrases.

4.2.4 Connection of Chords in Short Phrases

In this section we are interested in connecting triads in short phrases, while containing from four to six chords, keeping the simplifications and directions given in the previous section. Students should aim to obtain interesting solutions while using the available means at their disposal.

In their solutions, the pupils should observe some new directions that must be added to the previous set:

- the phrase should begin and end with a triad on the I^{st} degree. The reason is to introduce the feeling of a key into the phrase;
- repetition of chords should be avoided (except of course for the I^{st} degree at the beginning and the end of the phrase);

- each part should be melodic, that is, unpleasant intervals should be avoided;
- no voice should make a leap larger than a fifth (except for the bass, which we are restricting to be the root of each triad);
- consecutive leaps of a fourth or a fifth in the same direction should be avoided (because the first and last tones form a dissonance).

Figure 4.13 shows some of the possible ways of connecting triads that present common tones. Note that paths that contains nodes marked with rectangles or circles should not be considered, as the former correspond to phrases with less than four chords, and the latter present repetitions of triads.

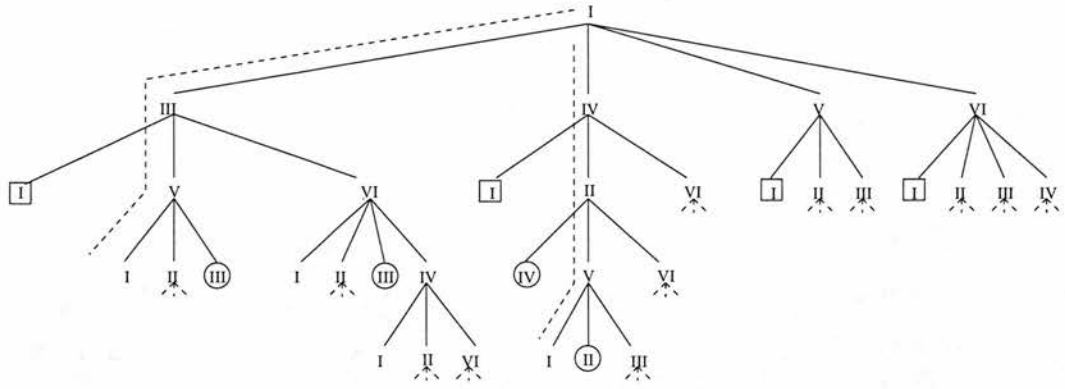


Figure 4.13: Some possible sequences of triads that consecutively present common tones

Figure 4.14 presents examples of appropriate connections of triads that correspond to the sequences of triads indicated as dashed lines on Figure 4.13.

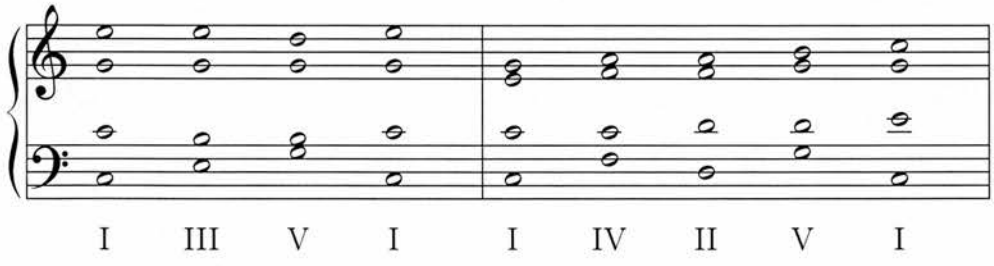


Figure 4.14: Examples of connection of triads in small phrases

The next section deals with how to use the VIIth degree on phrases.

4.2.5 The VIIth Degree

The triad on the VIIth degree presents a diminished fifth that is heard as a dissonance. Dissonant tones in general should be carefully introduced with a euphonious chord and resolved into an equally euphonious chord. For the specific case of the triad on the VIIth degree, the following guidelines should be used:

- *Preparation:* use only triads on the IInd and IVth degrees, as they present as a consonant the dissonant tone, that should be sustained on the same voice;
- *Resolution:* use only the IIIrd degree, as it provides a strong jump of a fourth above (or fifth below) on the root.
- The dissonant tone itself is resolved by moving a step downward.

The student should practice these preparations and resolutions (II-VII-III or IV-VII-III) as the ones shown on Figure 4.15.

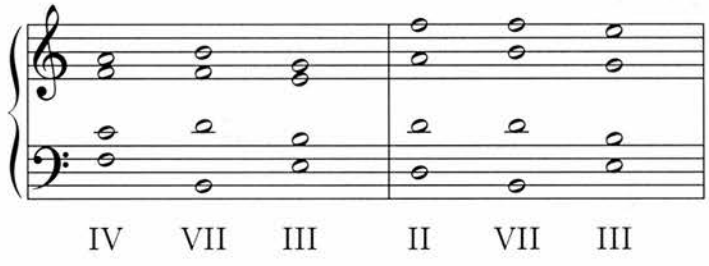


Figure 4.15: Use of the VIIth degree in chord connections

Some of the previous directions should be revised when using the VIIth degree. In fact, when *doubling degrees* the order of preference after the octave should now give precedence for the third over the (diminished) fifth, because of the dissonant nature of the latter. While movement to chord VII should retain common tones, movement from chord VII in general should not, as exemplified in Figure 4.16.

After practicing the use of the triad on the VIIth degree, the student should introduce the use of this chord in small phrases. A new question (number 2 below) should be added to the previous guidelines for connecting chords:

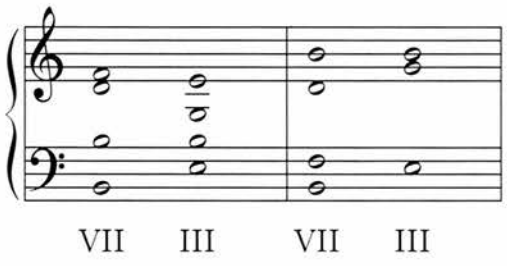


Figure 4.16: Examples of problems doubling degrees and sustaining common tones of the triad on the VIIth degree

1. Which tone is the bass tone? The root.
2. Which tone is dissonant? If there is a dissonance, then prepare and resolve it.
3. Which are the common tones? Wherever possible try to sustain them.
4. Which tones are still missing?

4.3 Summary

This chapter has introduced part of the assumed background information for beginners starting to learn through Schoenberg's method. Also, a formalisation of part of Schoenberg's method of teaching harmony has been presented. This formalisation is used to inform the design of the human-computer interface described in the next chapter, and also in the design of the learning environment described in Chapter 7.

Chapter 5

Design of the Interface

5.1 Introduction

As can be seen from chapters 1 and 4, Schoenberg's harmony teaching method is based on an exploration of the harmonic possibilities of chord connections under the guidance of a tutor, who is in charge of supervising[1] the sequencing of material according to the achievements of the student. This way of teaching seems to be particularly suitable for modelling under the Guided Discovery Tutoring framework (Elsom-Cook, 1990a). In this framework the internal representation of the domain is as important as the external representation at the interface:

> *An appropriate environment is one which helps a learner to make explicit his or her own model of the educational setting and use the environment to refine that model.*
>
> (Elsom-Cook, 1990b, p. 4)

This chapter describes the main components and functionality of the prototype human-computer interface used in the study described in Chapter 6. The relationship between the theoretical constraints of the teaching method chosen and the features of an interface that not only adheres to it but also provides a simple, intuitive and easy interaction for this particular task, is made explicit.

[1] The student has responsibility for defining the sequence to work with, based on instructions from the tutor

5.2 Theoretical Constraints

As described in Chapters 1 and 4, Schoenberg's harmony teaching method is centred on exercises on connection of chords that aim to foster the development of the student's harmonic sense. This development is constructed along a series of exercises that "derive the nature of chord connections strictly from the nature of the chords themselves, putting aside rhythmic, melodic, and other considerations" (Schoenberg, 1989, p. 13). His belief that "the principle aim of harmony instruction is to connect chords with an ear to their individualities" (Schoenberg, 1989, p. 14) explains why he disregards principles, such as the ones described below, that are central to traditional harmony teaching methods:

harmonic analysis The analysis of the harmonic functions implied by melodies extracted from well known pieces is necessary in traditional methods. Schoenberg's strongly opposes this principle (see § 1.4.1);

rhythm Traditional methods usually take rhythm into account not only during the harmonic analysis step, to give clues about possible underlying and acceptable cadences for a particular melody, but also in exercises involving the construction of different simultaneous melodies implied by these particular harmonic progressions. Schoenberg's method does not take into account rhythm and other musical elements (see § 1.4.1). The proposed exercises involve melodic lines that are rhythmically the same (*homophonic*) and beats or bars are not considered anywhere in his proposed curriculum;

The exercises proposed in Schoenberg's teaching method differ from most other teaching methods in that they do not involve a melody to be harmonised, based on accepted tonal music chord progressions. Rather, the main principles of his method involve:

- a definition of a particular sequence of chords described as a sequence of Roman numerals representing scale degrees (see § 4.2). The choice of sequence is dependent on the current knowledge of the student;

- the insertion of notes vertically, one at time and following a well defined order, while observing *chord positioning rules*;
- the completion of chords from left to write while observing, in addition to the chord positioning rules, the *chord connection rules.*

The four steps that need to be performed when solving a typical exercise following Schoenberg's principles are described in Section 1.4 and exemplified in Figure 1.5 for a close position initial chord. Figure 5.1 illustrates these steps for an open position initial chord, showing additionally the order in which the notes must be selected, as indicated by the Arabic numerals beside the notes. For the reader's convenience, the steps are summarised below.

Step 1: Chord sequence definition

Figure 5.1(a) illustrates a typical degree sequence that can be chosen when the student is practicing the connection of chords having common tones is small phrases;

Step 2: Note assignment for chord 1

Figure 5.1(b) shows the construction of the first chord, assuming open position for it. The bass voice should be the first one to be defined, followed by the soprano voice. The other voices must then be completed according to the selected position of the chord.

Step 3: Note assignment for the next chord

Figure 5.1(c) depicts the construction steps for the chord immediately to the right of the last constructed chord. In addition to observing both the chord construction constraints and the chord connection constraints, the following order for the note assignment must be followed: the first voice to be assigned must be the bass voice, followed by the voices that must hold the common tones, and then the other voices;

Step 4: Repeat Step 3 to all remaining chords

Figure 5.1(d), 5.1(e) and 5.1(f) show the repetition of step 3 until notes are assigned to all chords of the sequence.

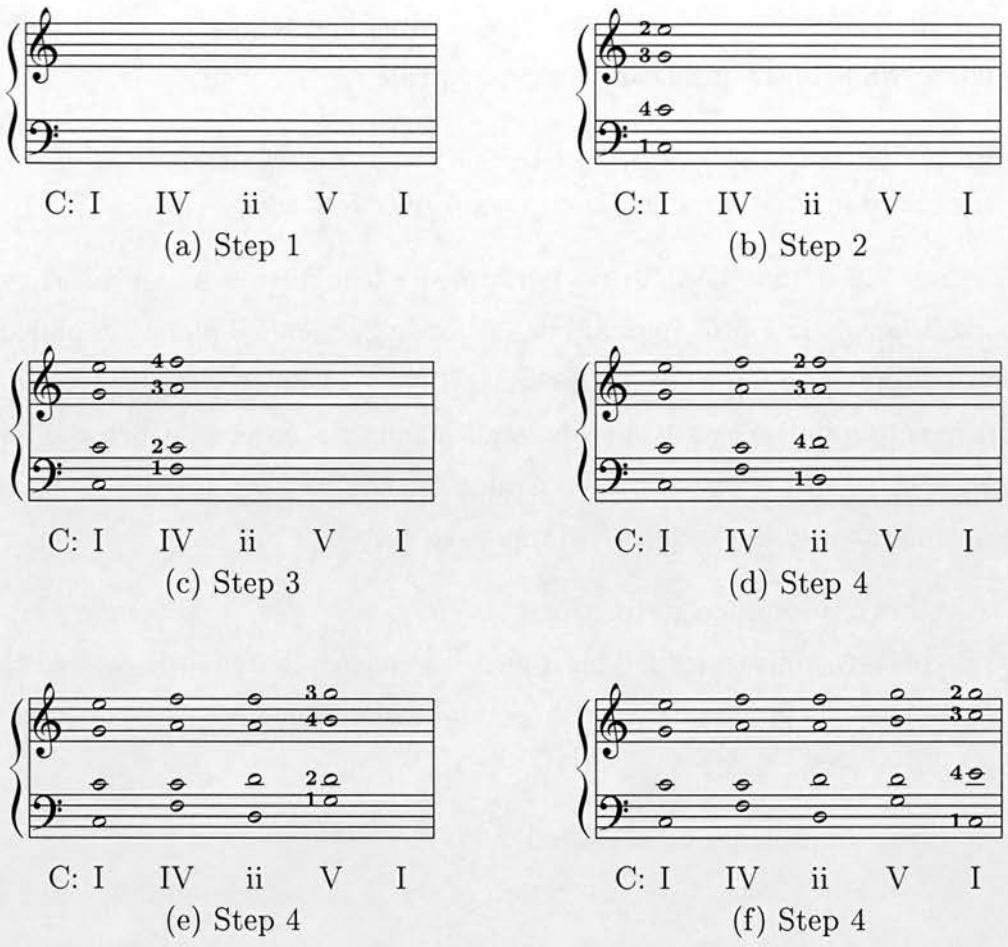


Figure 5.1: Steps into the solution to an exercise

5.3 Features

The main features of the interface were based on the constraints described in section 5.2, and detailed below.

vertical insertion and deletion of notes this requires allowing students to insert or delete notes within a vertical region of a musical score, exactly one note wide;

left to right construction this requires allowing the student to move to the chord immediately to the right of the current one after its construction if

the chord is well formed.

These features were refined, improved and expanded as informal piloting sessions were carried out by three evaluators with prototype versions of the interface. These piloting sessions involved several interactions with the evaluators, where they explored and played with older versions of the prototype, providing comments on potential difficulties on the use of the interface and suggestions for improvements.

The features described in this Section were coded in the Tcl/Tk language by the author, who also coded into bitmaps the pixels' image of the musical symbols. The Tcl interpreter/Tk toolkit language was chosen because of its vast library of graphical *widgets*, which eases the task of developing graphical user interfaces, and because it has been ported to Unix, Windows and Macintosh platforms. The prototypes described in this thesis were developed under the Unix environment, for which Tcl/Tk is best suited, and the two kinds of platforms used on the development of the prototypes and on the studies described in the following chapters were: a Sun workstation (Ultra-5 or Ultra-10) running the Solaris operating system, and a Toshiba Satellite notebook running Linux Red Hat operating system.

The Prolog language was used for chord representation and recognition, and the following excerpt of code exemplifies how a chord I in the close position and with the bass note on the root degree and the soprano note on the fifth degree is represented (see Section 5.6.2):

```
%
% Chords on the 1st degree - close root position (fifth on top)
%
chord([note(Ob,Pb,natural),note(Ot,Pt,natural),note(Oa,Pa,natural),
  note(Os,Ps,natural)],1,cr1) :-
  Pb = 1 , Pt = 1 , Pa = 3 , Ps = 5,
  Ob < Ot, Ot = Oa, Oa = Os.
```

5.3.1 Musical Canvas

Figure 5.2 shows the musical canvas for our initial prototype interface, which is compliant with Schoenberg's theoretical principles. User actions such as insertion or deletion of notes can take place only within the designated rectangles. The height of the rectangles allows insertion of notes within the piano pitch range.

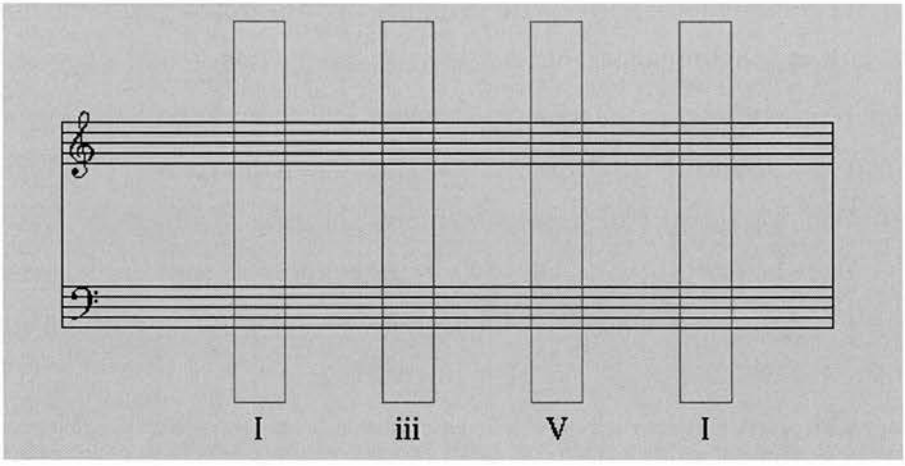


Figure 5.2: "Sensitive" rectangles for note insertions

In order to force the student to follow the required left to right completion of chords, only one of the "sensitive" rectangles can be enabled at a time. In addition, each rectangle was split into two rectangles, as shown in Figure 5.3, for two reasons:

- to eliminate the ambiguity of the region between the staves (was the inserted note associated with the treble or with the bass stave?);
- to allow only two notes per stave, adhering to the four-part writing when only a treble and a bass stave is being used (soprano and alto voices written on the treble stave, and the tenor and bass voices written on the bass stave).

From now on, we will refer to the Roman numeral immediately below the sensitive rectangles, or the chord number within the sequence, as the *focused chord.*

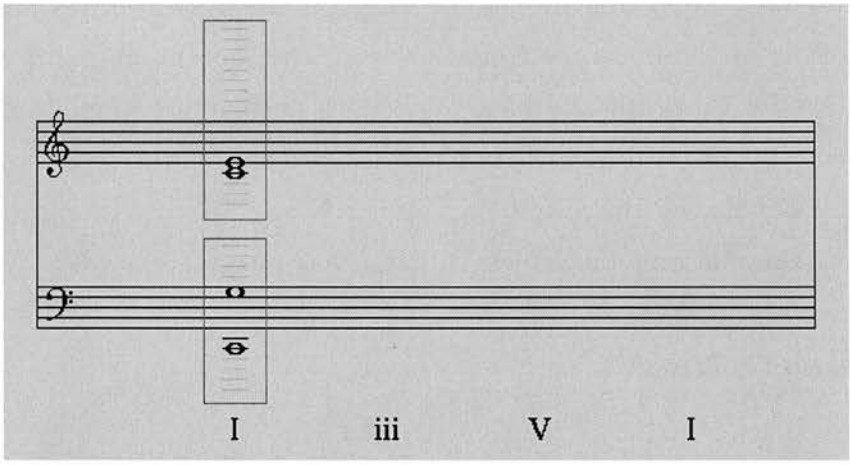


Figure 5.3: The focused chord

5.3.2 Mouse Buttons

The insertion and deletion of notes within the focused chord is made through the buttons of the mouse, whose behaviour is very similar to the one presented in most graphical programs, as described below:

insert note The student can insert notes simply by clicking the left mouse button on either sensitive rectangle of the focused chord. A maximum of four notes can be entered on the current chord, two on the treble stave (the top one) and two on the bass stave (the bottom one);

delete notes previously inserted notes can be deleted – within the current active rectangles – by means of pressing the right button of the mouse on a note;

In addition to the functionality of the buttons of the mouse, the Shift–Left Mouse combination enables the student to toggle the alteration of a note[2].

5.3.3 Insert Note

The insertion of notes can be made by pressing the left button of the mouse within a rectangular area on the canvas. There is a maximum limit of four notes per

[2]This feature is not essential for the stages of the curriculum we are dealing with, but it allows the student to experiment with all pitches within the range of the voices.

chord required by the so called four-part writing. As the only staves provided, as required by the method, are the treble stave for the soprano and alto voices and the bass stave for the tenor and bass voices each one can accommodate only two notes per chord. Ledger lines are presented in grey to help the insertion of notes, and these lines between the note being inserted and the stave are automatically emphasized (they become black) when the note is inserted.

5.3.4 Delete Note

Notes can be deleted by pressing the right button of the mouse on an existing note within the focused chord. Figure 5.4 shows the effect of deleting from Figure 5.3 one note from each stave. Alternatively, the *Undo* button can be used to erase

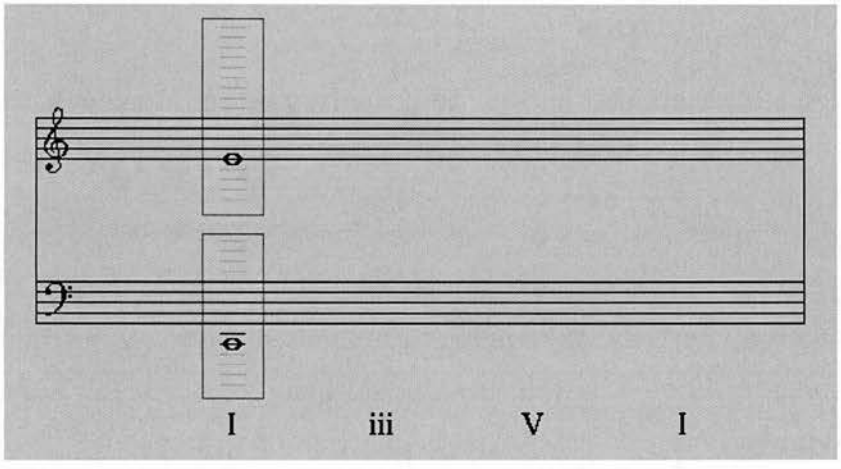


Figure 5.4: Deleting notes from the current chord

the last inserted note (see the section 5.3.5). In both cases, ledger lines are deemphasized consistently with the notes of the current chord currently being presented on screen.

5.3.5 Interface Buttons

The interface buttons enable students to start a new exercise, to play the constructed chords and sequences, to change focused chords within the sequence and to undo actions. The buttons are presented in Figure 5.5, and described below.

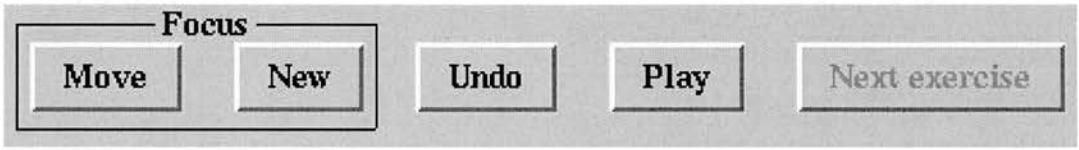


Figure 5.5: Interface buttons

Next exercise This button becomes active when an exercise is finalised, and enable students to move to the next task;

Play enables the student to listen to the whole sequence that appears in the musical canvas;

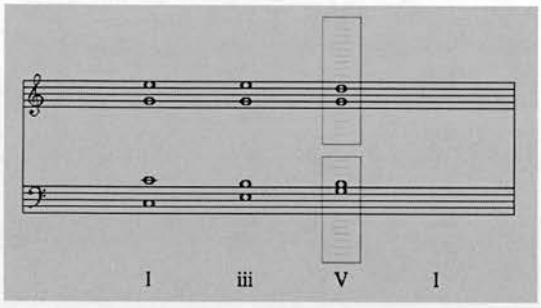
Focus buttons These buttons enable students to change the focused chord, moving the focused chord horizontally in the sequence as follows.

New enables students to move to the chord immediately to the right of the current one, as long as the current focused chord is a correct one. If the current chord is not a correct one, the focused chord is not changed and a feedback message (see § 5.4) is presented to the student. The prototype interface does not verify the correctness of the connection;

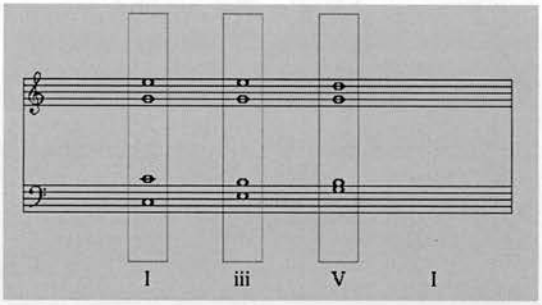
Move Focus enables the student to return to a previous chord, in order to change its notes. Figure 5.6 illustrates this mechanism: Figure 5.6(a) shows the musical canvas just before the <Move> button is pressed; Figure 5.6(b) shows that after the <Move> button is pressed sensitive areas associated with all chords previously worked out appear on the musical canvas; and Figure 5.6(c) shows what happens when the student selects, using the left button of the mouse, the first chord of the sequence. At this point the user can delete or insert notes within the current focused chord using the mouse buttons as before, and to focus another chord using any of the buttons as long as the focused chord is a correct one;

Undo enables the user to remove previous actions on the interface, which are stored in a stack. Only actions executed by the mouse buttons and on focus

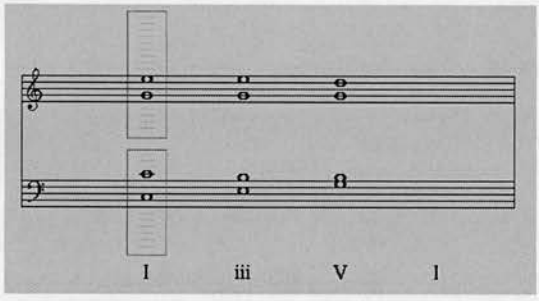
buttons can be undone.



(a) Before pressing the <Move> button



(b) After pressing the <Move> button



(c) First chord selected

Figure 5.6: The effect of the <Move> button

5.4 Instructions and Feedback

Instructions about the tasks and the feedback from the system about the correctness or not of the constructed chords are given in the same text window. Figure 5.7 shows the interface's window, in which instructions ("Construct the sequence of chords shown") and feedback ("Chord I, close root position, fifth on soprano") appears on the same text widget. The chord recognition process, which controls the feedback messages given, is a pattern-matching of the user's input chord with a Prolog database of chords as described in Section 5.3.

The feedback for the prototype was limited to the identification of a correct chord, as shown in Figure 5.7 above, or incorrect chord, in which case the message "the chord is incorrect" is presented. The environment built on top of our

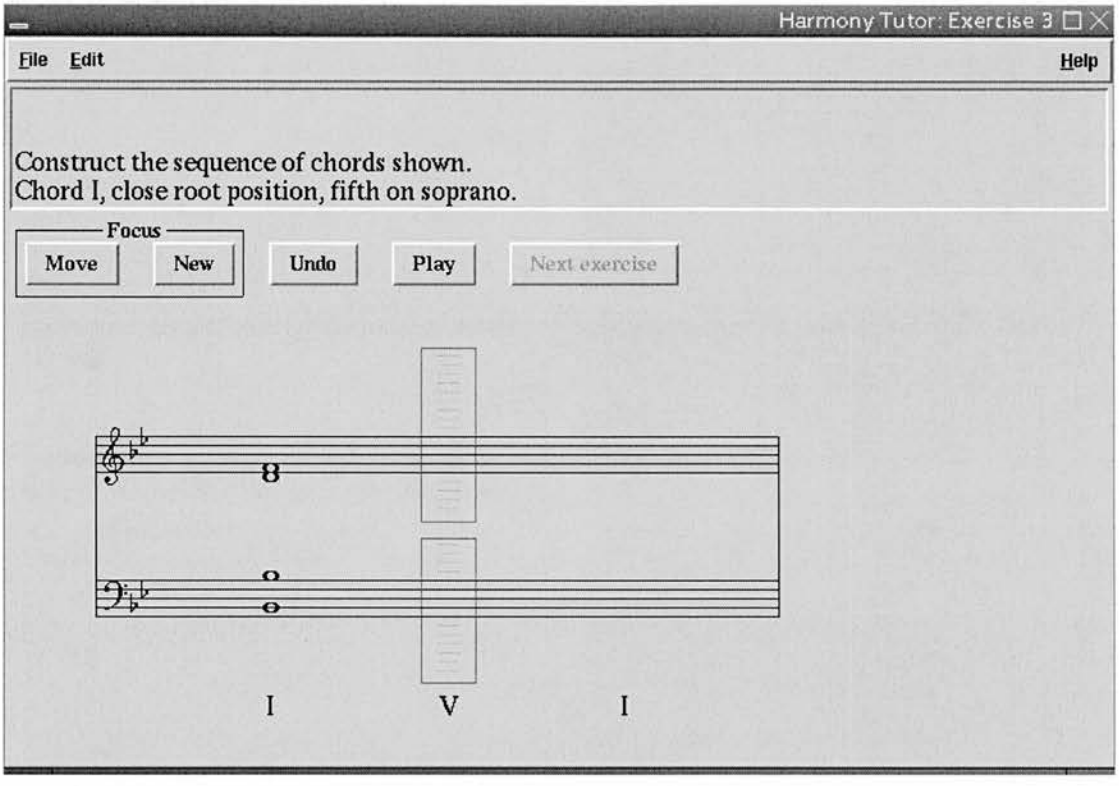


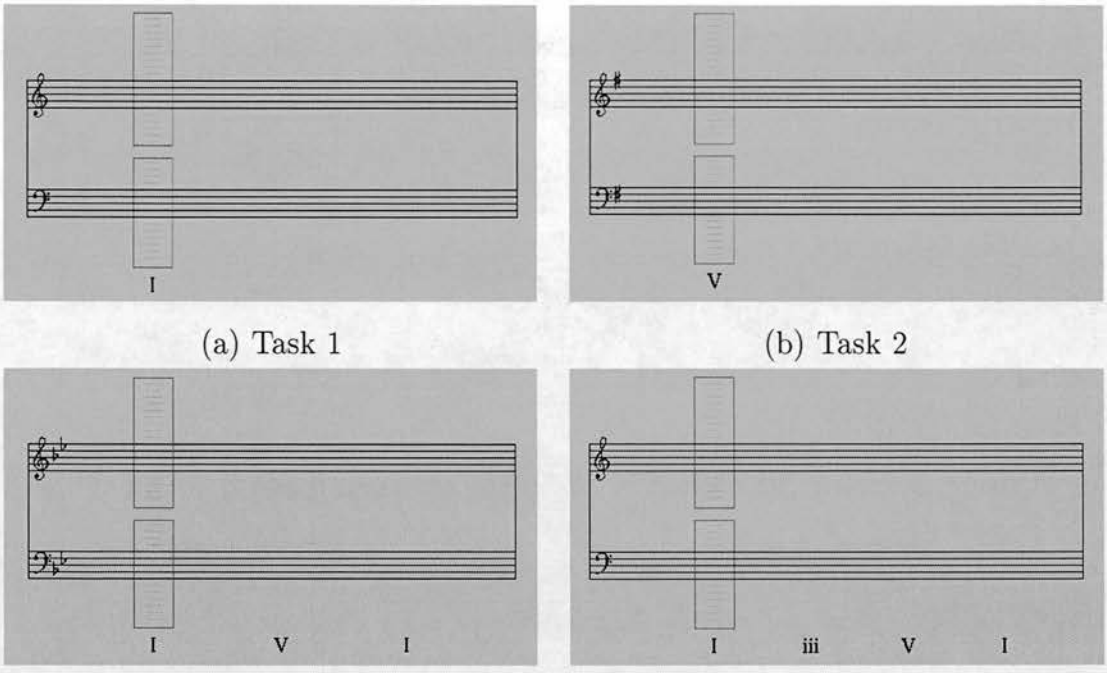
Figure 5.7: The interface's window

interface expanded the feedback messages (see Section 7.1.5) presented to the user.

5.5 Tasks

The tasks embedded in the interface, which were used in the evaluation study described in Chapter 6, are shown in Figure 5.8. The tasks require the construction of chords (Task 1 and 2) or sequences of chords (Tasks 3 and 4) for the major key signature specified on the staves and for the degrees presented on the musical canvas.

This thesis deals only with major mode materials and, eventhough the prototypes described in this chapter and in Chapter 7 were capable of (see Section 5.6), no minor mode materials were presented in the studies described in Chapters 6 and 8. The main reason is that the time scale involved in implementing and



(a) Task 1 (b) Task 2

(c) Task 3 (d) Task 4

Figure 5.8: The tasks for the evaluation study

evaluating a more comprehensive version of Schoenberg's method than the one presented in this thesis is not compatible with that of a Ph.D. research, and a much longer time scale was needed.

5.6 Score Representation

This section describes the score representation adopted. Onset time and duration of musical events were not considered in the representation as the teaching method does not involve rhythm, and all the musical events present the same duration. The onset time is implicitly represented by the order of the events.

5.6.1 Chord Sequence

A chord sequence is represented as

$$\textbf{sequence(Key, Mode, [chord}_1\textbf{, chord}_2\textbf{, ..., chord}_n\textbf{])},$$

where

Key is the name of the key signature (C, F♯, etc...);

Mode is the name of the mode of the diatonic scale (major, minor)[3];

chord$_i$ is the description for a chord, given below, which is relative to the above key signature and diatonic scale mode.

5.6.2 Chord

A chord is represented as a list of notes as below, where the subscripts b, t, a, and s denote respectively the bass, tenor, alto and soprano voices:

chord([note$_b$**, note**$_t$**, note**$_a$**, note**$_s$**])**

5.6.3 Note

A note is represented as **note(octave,degree,alteration)**, where:

octave = 0..7, where 1 is associated to the first occurrence on a piano keyboard range, from left to right, of the key signature note[4];

degree refers to the scale degree number ($\hat{1}$, $\hat{2}$, $\hat{3}$, $\hat{4}$, $\hat{5}$, $\hat{6}$, $\hat{7}$) of the diatonic mode defined in the chord sequence representation;

alteration represents the alteration (♭, ♮, ♯, ♭♭, ♯♯) in relationship to the diatonic scale mode and key signature defined in the chord sequence representation. Therefore **note(3, $\hat{7}$, ♮)** for **Key = B** and **Mode = major** refers to the note B^b below the central C of a piano.

5.7 Summary

This chapter has presented an overview of the theoretical constraints which guided the design of the features of the described human-computer interface. Information

[3]In this dissertation only the major mode was used.

[4]Therefore to transpose a sequence to another key is just a matter of changing the Key variable in the chord sequence definition.

about the score representation and the patern-matching process, which guides the feedback mechanism, is also given. The tasks embedded in the interface prototype, which are used in the evaluation study described in the next chapter, were also presented.

Chapter 6

Evaluation of the Usability of the Interface

This chapter describes a study intended to evaluate the usability of the human-computer interface described in chapter 5. It begins with an overview of the interface mechanisms and how they relate to the pedagogical constraints of Schoenberg's method, before introducing the methods used and deriving specific questions from the main question we are trying to answer: *Does the interface allow the user to work with sequences of chords while enforcing Schoenberg's constraints?*

6.1 Introduction

The evaluation of intelligent teaching systems has traditionally been conducted in two phases: the formative and summative evaluations. Formative evaluation is carried out during the development of a system to obtain information that might be used to modify and improve the system's operation. Summative evaluation, on the other hand, aims to evaluate complete systems and support formal claims about a system or the techniques used in it. This chapter is concerned with the formative evaluation of the interface described in the previous chapter. The summative evaluation of the learning environment described in the next chapter is carried out in Chapter 8.

Different methodologies for assessing individual components or whole systems have been used in the evaluation of intelligent teaching systems. Techniques ranging from informal methods in formative evaluation (Twidale, 1993) to methods based on quantitative measurements in summative evaluation (Legree et al., 1993) are being used. Most techniques are adapted from fields such as education, psychology and computer software design, as reviewed in Mark & Greer (1993), who showed that there is no agreed standard methodology for evaluating intelligent teaching systems. However, some general principles such as the ones identified by Shute & Regian (1993), are being used to guide the complex process of designing evaluations of learning environments. These principles, reproduced below, were used as guidelines in the design of the current evaluation.

- Delineate the goals of the tutor;
- Define the goals of the evaluation study;
- Select the appropriate design to meet the defined goals;
- Instantiate the design with appropriate measures, number and type of subjects, and control conditions;
- Make careful logistical preparation for conducting the study;
- Pilot test the tutor and the study; and
- Determine the primary data analyses as the study is planned.

The interface, described in chapter 5, was designed to provide an embodiment of Schoenberg's method for harmony teaching in a direct manipulation environment. This embodiment was achieved by means of identifying the constraints associated with individual parts of the curriculum and embedding them in an interface, through which the user can interactively create and listen to sequences of chords, while getting a limited amount of feedback from the system.

This section describes, in addition to the general constraints of the method and interface mechanisms, the questions derived from the main question and the

general methods used to answer them. The next section presents the specific methods adopted, with the results being presented in the following section.

6.1.1 Constraints

The interface, described in chapter 5, was designed to have constraints that correspond to the ones adopted by Schoenberg in his harmony teaching method. Musical constraints evolve as the student progresses through the curriculum, in such a way that new constraints can be added while others can be relaxed, disregarded or changed. The particular constraints considered in this study are the ones Schoenberg adopts for the initial stages of learning, and they are described below:

chord constraints

1. chords can present one of the following *positions*:

   close when no other chord tone can be inserted between two adjacent voices of the upper three voices; or

   open when one chord tone can be inserted between two adjacent voices of the upper three voices;

2. chords are constructed individually, from left to right;

3. the movement to the right of the current chord is allowed only if the correctness and completeness of the current chord is fully observed [1];

notes constraints

1. only the notes of the associated diatonic triad (represented by a Roman numeral) can be used;

2. two notes must be placed on the treble stave, for the *soprano* and *alto* voices;

[1] another constraint was added to the interface, as described in Section 6.1.4, to also accommodate the movement to the left of the current chord.

3. two notes must be placed on the bass stave, for the *tenor* and *bass* voices;
4. repeated pitches are not allowed [2];
5. the bass note must be the root degree (as indicated by the Roman numeral below the chord).

6.1.2 General Questions

Given the constraints described on Section 6.1.1, a sequence of degrees and a blank stave, the main question addressed by this study can be decomposed as follows. Can the user:

- insert notes to construct the first chord?
- correct notes in the chord given feedback about incorrectness of the chord?
- move forward to construct a new chord, having constructed one chord?
- insert/delete notes to construct the new chord?
- move forward and backward in the sequence?

6.1.3 General Methods

The evaluation is based on the *cognitive walkthrough* method, where expert evaluators are asked to solve tasks using the interface and to identify problems in attaining the goals [3]. The main focus of method is to establish how easy a system is to learn through exploration and to check it for potential usability problems.

While the evaluators stepped through the sequence of actions required to accomplish each task, their actions with the interface were logged on dribble files and they were video-recorded. The dribble files provided not only an indication of some of the errors made up by the users but also quantitative measures of

[2] Actually, notes with the same pitch are allowed in different staves, but not in the same one. See Sections 6.3.2.3 and 6.3.2.4 for examples.

[3] The cognitive walkthough method in fact involves task scenarios devised and scrutinised by the software developers themselves at the early stages of design, who role play a user working with the interface.

user performance such as which mechanisms were used and when they were used. The video-tape recording provided an indication, when associated with the time stamps on the dribble files, that helped in the identification of some of the possible slips or intentional changes made by the evaluator, based on reactions such as surprise or agreement while the actions were taken.

An observation check list was considered and used in the pilot study. However it was found that little information could be obtained during the interaction. The reasons were that, due to the speed of the evaluators with the interface (mainly with the mouse buttons) and the large number of potential solutions for the tasks set, there was too little time for the observer to note the intended actions of the evaluators. Consequently, all analysis in the main study was based on the dribble files and video recording.

6.1.4 The Interface Mechanisms

In the description that follows of the mechanisms of the interface, shown on Figure 6.1, the term *current focus* is used to refer to the area inside the rectangles where notes can be inserted or deleted, and the term *current chord* is used to refer to the chord associated with the current focus.

In order to provide the user with the option of rebuilding previously constructed chords while still adhering to Schoenberg's guidelines, a specific constraint referring to the movement to the left must be added to the set of chord constraints on page 75 as follows:

4. the movement to the left of the current chord is allowed only if

   - the correctness is observed for a complete (4-voice) chord;
   - the correctness of a complete (4-voice) current chord is observed;
   - its notes are part of the triad, the bass is in the root degree and the chord is the rightmost constructed one. In this case the position (see chord constraint number 1 on page 75) is not considered.

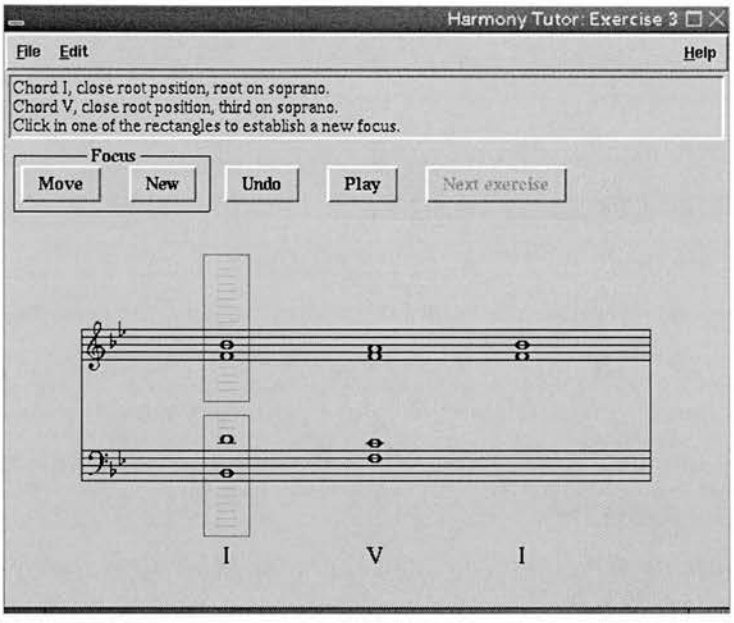


Figure 6.1: The interface of the harmony teaching environment

The interface mechanisms are described below, where the effects take place only when the constraints described are observed.

Insert enables the user to insert notes within the current focus by means of pressing the left button of the mouse on a line or space of a musical stave.

Delete enables the user to delete notes within the current focus by means of pressing the right button of the mouse on an existing note.

Focus enables the user to modify where the current focus is. Two buttons are provided:

- New Focus – enables the user to move to the chord immediately to the right of the current one. The movement is made only when the current chord is correct and complete;
- Move Focus – allows the selection of any of the chords previously constructed chords when the constraints in Section 6.1.1 (plus chord constraint 4 in this section) for the current chord are observed. The selected chord becomes the new current chord.

Play enables the user to listen to all of the constructed chord sequence, even if it is not finished yet.

Undo enables the user to undo the last actions on the interface (except for the Play button) in the reverse order to that in which they were made. As a result of pressing the "Undo" button, the last action is removed from the stack of successful actions and its effect is undone as described below:

- Undo Insert – last inserted note is removed from the current chord;
- Undo Delete – last deleted note is reinserted in the current chord;
- Undo New Focus – focus returns to the chord to the left of the current one;
- Undo Move Focus – focus returns to where it was before the Move focus action.

Table 6.1 summarises the expected effects from individual actions for the interface mechanisms.

6.1.5 Specific Questions

The general questions in Section 6.1.2, for this particular interface, can be rephrased as the following set of questions:

1. Can the user insert notes, using the left button of the mouse within the rectangles, to construct a chord?
2. Can the user delete notes using the right button of the mouse on an inserted note ?
3. Can the user distinguish between "Undoing" an insertion of a note and "Deleting" a note or does this cause confusion?
4. Can the user distinguish between "Undoing" a deletion of a note and "Inserting" a note or does this cause confusion?

Mechanism	Action	Effect
Insert	left mouse [a]	Insert a note
Delete	right mouse [b]	Delete a note
Focus	New Focus	move the chord focus to the right
	Move Focus	move the focus to an existing chord
Undo [c]	Insert	last inserted note is removed
	Delete	last deleted note is reinserted
	New Focus	focus returns to the chord to the left of the current one
	Move Focus	focus returns to where it was before the Move Focus action

Table 6.1: Interface mechanisms

[a] within the current focus
[b] within the current focus and on a previously inserted note
[c] for this mechanism the action refers to the last action from the user on the interface

5. Can the user move on to the next chord by clicking the "New Focus" button?

6. Given a partially constructed sequence of chords, can the user use the "Move Focus" button to go back to a previous chord and change its notes?

7. Given a partially constructed sequence of chords, can the user use the "New Focus" button to move forward to the chord immediately to the right in relationship to the current one (if the current chord is not the rightmost worked chord)?

8. Given a partially constructed sequence of chords, can the user use the "Move Focus" button to move forward to a previously worked chord (if the current chord is not the rightmost worked chord)?

6.2 Method

The evaluation was carried out by means of the analysis of the several materials such as questionnaires and dribble files (see Section 6.2.2) produced during the interaction, and also by means of analysis of video observation of the evaluators interacting with the environment. An interview took place at the end of the interaction, and it aimed to collect the evaluator's overall impression of the interface.

6.2.1 Participants

In order to perform a proper evaluation of such an interface, some expertise in tonal harmony was required from the evaluators. The evaluation of the interface was carried out by three music teachers with expertise in tonal harmony teaching. All of them had a large experience as composers and/or performers. Their musical interests and specific expertise, however, varied widely as described below:

Evaluator A is a researcher on computational music cognition with substantial experience in harmony teaching and composition. He is a senior lecturer, and Director of the Electroacoustic Music Studios, at the Faculty of Music at the University of Edinburgh.

Evaluator B is a organist and conductor with a M. Mus in Composition from the University of Edinburgh and experience in harmony teaching.

Evaluator C is a double-bass player with a B. Mus in Composition from the University of Campinas (Brazil) and experience as a composer and jazz performer. He is currently teaching on the M.Mus in Jazz programme at Napier University.

Even though a higher number of test users was desirable to be used in this evaluation study, there is evidence gathered from 36 published usability studies that the benefits to cost ratio for running a medium-size usability study is maximum for three users (Nielsen, 1993, chap. 6).

6.2.2 Materials

The materials used in the study are:

prototype version 1.0 of the interface (see section 6.1.4);

handout intended to provide the evaluators with information not only about the prototype but also about the tasks to be performed. The handout is made up of three sections (see Appendix A):

Theoretical Background for all Tasks gives the constraints that must be observed and the steps that must be taken while performing the tasks;

Using the Interface gives a description of the functionality of the interface and of tasks 1 and 2 of constructing single chords;

Tasks gives a description of the tasks 3 and 4 of connecting chords;

dribble file generated by the system while the evaluators were performing the required tasks, it stores information about every single action of the user with the interface, along with time stamps;

semi-structured interview sheet containing questionnaires intended to collect background information from the evaluator and comments regarding the various interface mechanisms and their effects on the evaluator's performance;

observation check list a list of items the observer, by direct observation of the interaction, must check and provide comments on in relation to how the evaluator is performing the tasks (dropped after the pilot study);

video-tape recording intended to complement the information provided by the previous materials, particularly in helping in the identification of the evaluator's intentions while performing particular sequences of actions.

6.2.3 Procedure

The study was run individually and separately with each evaluator. The observer was responsible for setting up the physical environment, for collecting information from the evaluator through a questionnaire and a semi-structured interview, for making direct observation and for providing explanation of the interface's mechanism during the interaction if needed. These steps are described below:

Initial set up the observer performs the following steps before each interaction takes place

- check printed materials (handout, observer script, observer check list and semi-structured interview sheet);
- start the prototype and make sure the audio level is appropriate;
- position the camcorder and start the recording sessions.

Background information the observer collects background information from the evaluator and fills the first section on the semi-structured interview sheet (see AppendixA).

Handout (1) the observer asks the evaluator to read the first section of the handout (Theoretical background for all Tasks), and highlights the constraints to be observed in this study.

Handout (2) the observer asks the evaluator to read the second section of the handout (Using the Interface), and provides the evaluator with a verbal descriptions of the mechanisms to be used during the interaction.

Familiarisation with the interface the observer asks the evaluator to perform tasks 1 and 2, which involve the construction of a single four-voice chord, using the insertion, deletion and Undo mechanisms of the interface. While the evaluator is performing the tasks the observer fills the observation check list according to the evaluator's performance.

Task 3 the observer asks the evaluator to perform task 3, which involve the construction of a simple sequence of chords.

Task 4 the observer asks the evaluator to perform task 4, which involve the construction of a sequence of chords slightly more complex than task 3.

Interview the observer interviews the evaluator, asking questions from the second section of the Semi-structured Interview Sheet (see AppendixA). Specific questions about the level of difficulty the evaluator experienced while dealing with the interface mechanisms were posed, in addition to more general questions aiming to capture the overall impression of the evaluator about the interface.

After running the study the data from the materials was organised and analysed. The video-tape recording was used in the identification of some of the evaluators' intentions of their actions on the interface, although the precise identification of their reaction to actions that were very close together in time proved to be not completely reliable. However, the dribble files created during the interaction enabled a detailed graphical reconstruction of the user actions on the interface as presented in Section 6.3. This helped in the identification of some evaluator's intentions and in distinguishing between intentional or unintentional actions.

6.3 Results

The actions from the evaluators on each task are represented here through *action diagrams*, which are bidimensional plots where the vertical axis is used to represent pitches and the horizontal axis is used to represent time. To ease the identification of musical notes, a piano keyboard is used in very much the same way as in the piano-roll diagrams that can be found in most music software. However, in contrast to a piano-roll diagram, the events represent when and which actions were made on the interface, rather than being associated with the actual start or end of musical notes. Insertion or deletion of notes are represented by filled or empty circles respectively, while the undo insert and undo delete actions are represented by empty and filled squares respectively. To illustrate the de-

scribed notation, Figure 6.2 shows the possible pair of events that defines the *life cycle* of a note in the screen.

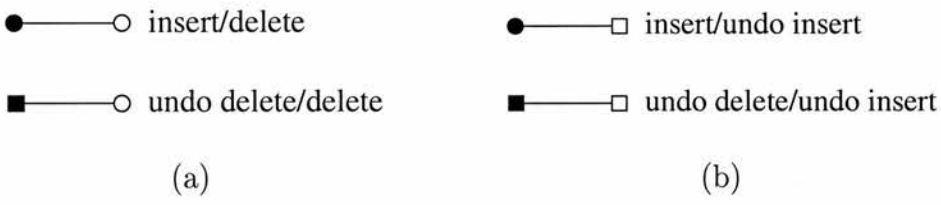


Figure 6.2: The representation of the life cycle of notes

Any number of actions can occur between the events shown in Figure 6.2(a), but for the life cycles shown in Figure 6.2(b), extra actions must come in the form of do-undo pairs of actions as in Figure 6.3.

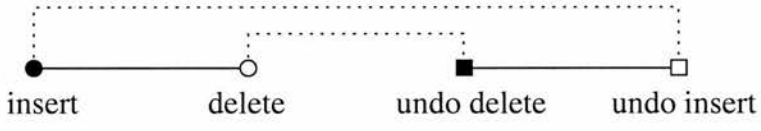


Figure 6.3: Do-undo pairs of actions

6.3.1 Evaluator A

Evaluator A is a University Senior Lecturer at the Faculty of Music from the University of Edinburgh. He has experience in the teaching of harmony and in the use of computer programs such as musical sequencers and notators. He found the mechanisms of the interface easy to use, and suggested this might be an useful tool to use in his own harmony teaching. When asked about possible improvements in the interface he made the following suggestions:

- change the cursor shape to help the user in the identification of a line or space in the musical canvas;
- enlarge the font size used for the feedback from the system;

- change the name of the New Focus button because, when the current chord is in the middle of a constructed chord sequence, one might think the next focused chord must be the leftmost non-focused chord (a *new* chord), which is not the one selected by this interface[4];
- allow the balancing of the volume of the voices.

6.3.1.1 Task 1

Evaluator A constructed almost immediately the open position chord shown in Figure 6.4(a) without inserting incorrect notes, which was then played a number of times through loudspeakers and headphones. These actions can be observed on the diagram shown in Figure 6.5 (page 88), which depicts the actions from evaluator A on the interface while engaged on the task of constructing a C-major chord. Table 6.2 gives an interpretation of the actions based on the observation of the video-tape recording and its transcription (Appendix A, page 215) along with the diagram of actions (Figure 6.5), and Table 6.3 gives a summary of the intentional actions and slips that does not include actions on the "Play" button.

(a) t = 45s (b) t = 179s (c) t = 190s

Figure 6.4: Task 1 chords constructed by evaluator A

Time	Action	Comments	Interpretation
20	Insert C_2	Practice	Insert
26	Delete C_2	Practice	Delete
continued on next page			

[4]After pressing the New Focus button, the next focused chord is the one to the right of the current one.

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Time	Action	Comments	Interpretation
27	Insert C_2	First note	Insert
40	Insert G_2	Second note	Insert
42	Insert E_3	Third note	Insert
45	Insert C_4	Fourth note	Insert
47	Play	Chord reproduced	Play
62	Play	Chord (+ noise) reproduced	Play
72	Play	Chord reproduced	Play
101	Play	Attempt to identify the top note	Play
109	Play	Attempt to identify the top note	Play
114	Play	Attempt to identify the top note	Play
118	Play	Attempt to identify the top note	Play
124	Insert C_5 failed	Attempt to modify the top note	Slip
152	Play	Using headphones	Play
160	Play	Using headphones	Play
167	Insert D_5 failed	Attempt to modify the top note	Slip
169	Undo insert C_5	Step taken to modify the top note	Undo
174	Insert C_5	Attempt to insert a different top note	Slip
177	Delete C_5	Removal of top note	Delete
179	Insert B_4	Insert deliberately a non-chord note	Insert
182	Play	Identify sound of top note	Play
187	Insert B_4 failed	Attempt to modify the top note	Slip
188	Undo insert B_4	Step taken to modify the top note	Undo
190	Insert D_5	Insert deliberately a non-chord note	Insert
192	Play	Identify sound of top note	Play
195	Undo insert D_5	Step taken to modify the top note	Undo
197	Insert C_5	Insert back original top note	Insert
199	Play	Identify sound of original top note	Play

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Time	Action	Comments	Interpretation
231	New	Chord accepted	New

Table 6.2: Actions from evaluator A on task 1

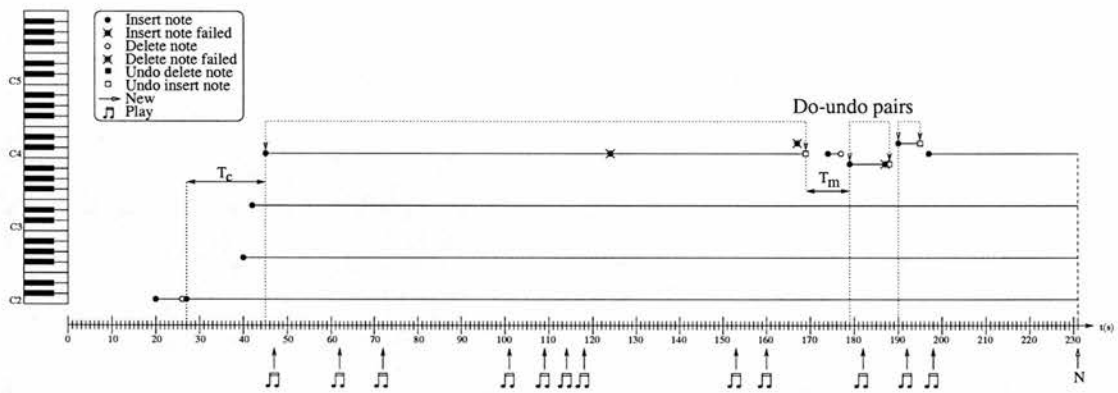

Figure 6.5: Task 1 action diagram for evaluator A

As the evaluator said he was not able to distinguish the (sound of the) top note from the other notes of the chord, he changed it to a note not belonging to the chord as shown in Figures 6.4(b) and 6.4(c). After listening to the effect of each change and making sure the top note was being produced, the evaluator returned the original top note to the chord, played it again once more before having the chord analysed and accepted by the system.

Action	Intentional				Slip	
	Insert	Delete	Undo	New	Insert	Insert fail
Number	8	2	3	1	1	3
Total	14				4	

Table 6.3: Summary of the actions from evaluator A on task 1

6.3.1.2 Task 2

Evaluator A constructed with ease the close position D-major chord in Figure 6.6(a) with only one slip, as can be observed from the action diagram in Figure 6.7. After the chord was played at 22s, the observer suggested the use of the "Undo" mechanism. The evaluator used this mechanism to remove notes from screen in order to exchange the original close position chord for the open position one shown in Figure 6.6(b). During this process, where the evaluator got used to the mechanism, some slips were made. His reaction to the "Undo Delete" at 50s, where a previously deleted note reappeared on screen, was a mix of slip and surprise ("Ops."[5]). After using the "Undo" button twice more he apparently agreed with the behaviour of the mechanism ("Oh, I see."). After that he inserted the two top notes of the chord in Figure 6.6(b) and played it, acknowledging he was happy with it. The task was finished when he pressed the "New" button and the chord was accepted by the interface.

Table 6.4 gives an interpretation of the actions from the evaluator, while Table 6.5 gives a summary of the intentional actions and slips, again not including actions on the "Play" button.

(a) t = 20s (b) t = 63s

Figure 6.6: Task 2 chords constructed by evaluator A

Time	Action	Comments	Interpretation
8	Insert D_3	First note	Insert
9	Insert A_3	Second note	Insert
continued on next page			

[5]references to what the evaluators said during the interaction will appear in double quotes within parentheses from now on. The full transcriptions of the interactions can be found in Appendix A

continued from previous page			
Time	Action	Comments	Interpretation
12	Insert D_4	Third note	Insert
17	Insert G_4	non-chord note	**Slip**
19	Delete G_4	Remove wrong note	Delete
20	Insert $F_4^\sharp$	Fourth note – see Figure 6.6(a)	Insert
22	Play	Chord reproduced	Play
40	Insert $F_4^\sharp$ failed	Note already existing	Slip
41	Undo Insert $F_4^\sharp$	Practice	Undo
45	Insert C_4	Note not part of triad	Slip
47	Undo Insert C_4	Remove wrong note	Undo
48	Insert D_4 failed	Note already existing	Slip
50	Undo Delete G_4	practice – reinsert deleted note	**Slip**
55	Undo Insert G_4	Remove wrong note	Undo Insert
56	Undo Insert D_4	Step taken to modify chord	Undo Insert
61	Insert $F_4^\sharp$	Third note	Insert
63	Insert D_5	Fourth note – see Figure 6.6(b)	Insert
66	Play	Chord reproduced	Play
73	New	Chord accepted	New

Table 6.4: Actions from evaluator A on task 2

Action	Intentional				Slip		
	Insert	Delete	Undo	New	Insert	Insert fail	Undo
Number	6	1	4	1	2	2	1
Total	12				5		

Table 6.5: Summary of the actions from evaluator A on task 2

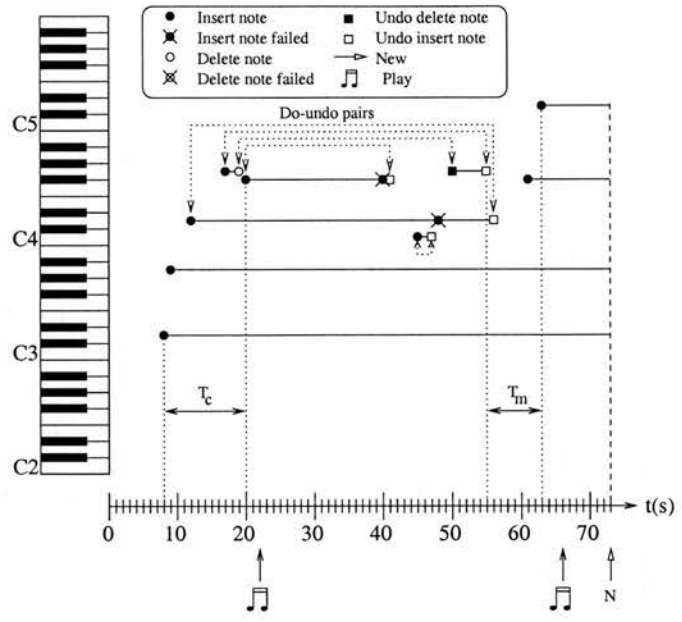

Figure 6.7: Task 2 action diagram for evaluator A

6.3.1.3 Task 3

Figure 6.8 shows the action diagram for evaluator A while performing task 3

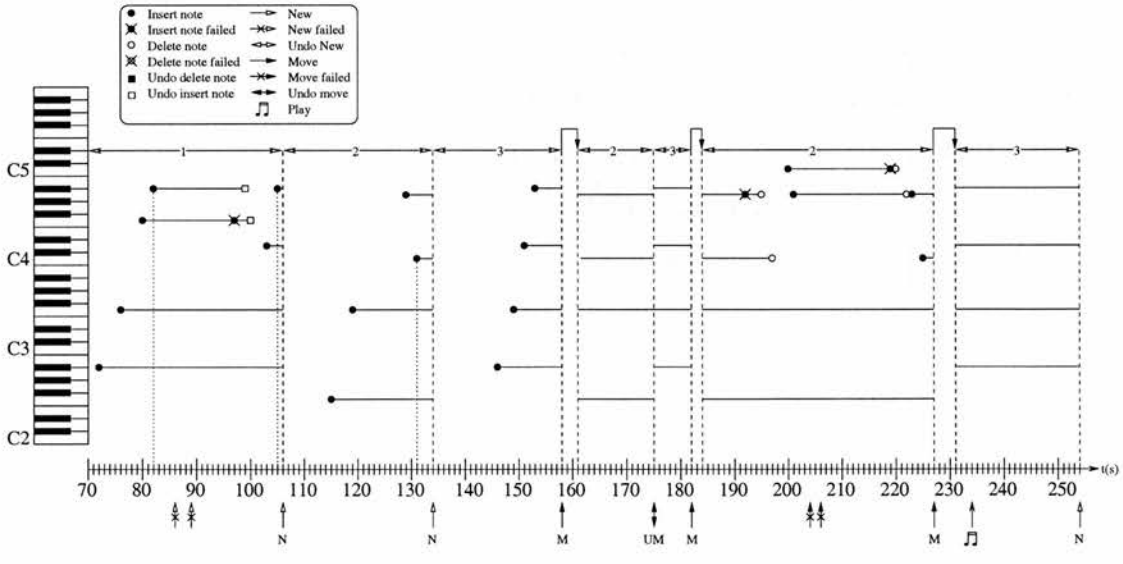

Figure 6.8: Task 3 action diagram for evaluator A

(sequence I – V – I on the key of B-flat major), while Table 6.6 (page 94) gives an

interpretation for these actions. The smaller ratio of slips/actions (see Table 6.7) shows that the evaluator was more confident in the use of the interface, even having initially constructed the chord shown in Figure 6.9(a), which was not accepted by the system as the third of the chord was missing. He apparently was trying to test the interface's behaviour to a wrong chord, and agreed with the system's refusal of acceptance of the chord ("Oh, yes. Good.") before modifying its top notes to the open position chord shown in in Figure 6.9(b) and having it accepted.

(a) t = 82s (b) t = 105s (c) t = 131s (d) t = 153s (e) t = 201s

Figure 6.9: Task 3 chords constructed by evaluator A

The second and third chords of the sequence were constructed without slips as the open position chords shown in Figures 6.9(c) and 6.9(d) respectively, which were accepted by the interface. After practicing a bit with the "Move Focus" mechanism, as suggested by the observer, the evaluator changed the second chord into the chord in Figure 6.9(e), which was not accepted as the spacing between the alto and tenor notes was larger than an octave. Again, the evaluator agreed with the system's refusal of acceptance of the chord ("Very good. Very good.") and after restoring the original top two notes to the second chord (as in Figure 6.9(c)) the sequence was played and the third chord accepted at 254s.

Chord	Time	Action	Comments	Interpretation
1	72	Insert $B_2^\flat$	First note	Insert
	76	Insert F_3	second note	Insert
	80	Insert F_4	third note	Insert
	82	Insert $B_4^\flat$	fourth note (Figure 6.9(a))	Insert
	86	New failed	chord with missing third	Slip
	89	New failed	chord with missing third	Slip
	97	Insert F_4 failed	note already existing	Slip
	99	Undo Insert $B_4^\flat$	remove fourth note	Undo
	100	Undo Insert F_4	remove third note	Undo
	103	Insert D_4	third note	Insert
	105	Insert $B_4^\flat$	fourth note (Figure 6.9(b))	Insert
	106	New	chord 1 accepted	New
2	115	Insert $F_2^\flat$	first note	Insert
	119	Insert $F_3^\flat$	second note	Insert
	129	Insert $B_4^\flat$	third note	Insert
	131	Insert C_4	fourth note (Figure 6.9(c))	Insert
	134	New	chord 2 accepted	New
3	146	Insert $B_2^\flat$	first note	Insert
	149	Insert F_3	second note	Insert
	151	Insert D_4	third note	Insert
	153	Insert $B_4^\flat$	fourth note (Figure 6.9(d))	Insert
	158	Move_a	chord 3 accepted	Move_a
2	161	Move_b	chord 2 selected	Move_b
3	175	Undo Move	chord 3 re-selected	Undo
	182	Move_a	chord 3 accepted	Move_a
	184	Move_b	chord 2 selected	Move_b
	192	Insert A_4 failed	note already existing	Slip
	195	Delete A_4	remove fourth note	Delete

continued on next page

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Chord	Time	Action	Comments	Interpretation
2	197	Delete C_4	remove third note	Delete
	200	Insert C_5	third note	Insert
	201	Insert A_4	fourth note (Figure 6.9(d))	Insert
	204	Move_a failed	wrong spacing between voices	Slip
	206	Move_a failed	wrong spacing between voices	Slip
	219	Insert C_5 failed	note already existing	Slip
	220	Delete C_5	remove fourth note	Delete
	222	Delete A_4	remove third note	Delete
	223	Insert A_4	third note	Insert
	225	Insert C_4	fourth note(Figure 6.9(c))	Insert
	227	Move_a	chord 2 accepted	Move_a
3	231	Move_b	chord 3 selected	Move_b
	234	Play	sequence reproduced	Play
	254	New	chord 3 accepted	New

Table 6.6: Actions from evaluator A on task 3

Table 6.7 gives a summary of the actions from evaluator A, where a single successful "Move" operation actually demands two actions from the user (Move_a and Move_b in Table 6.6).

Action	Intentional					Slip (fail)		
	Insert	Delete	Undo	New	Move	Insert	New	Move
Number	18	4	3	3	3	3	2	2
Total	31					7		

Table 6.7: Summary of the actions from evaluator A on task 3

6.3.1.4 Task 4

Figure 6.10 shows the actions from evaluator A while performing task 4 (sequence I–iii–V–I on the key of C major). Initially he constructed the first open position chord shown in Figure 6.11(a), which was accepted by the system. Then he started the construction of the second chord but changed his mind, returned the focus to the first chord and rebuilt it as the close position chord in Figure 6.11(b). With just a few slips, he constructed each one of the remaining chords of the sequence, as shown in Figure 6.11(c) to (e).

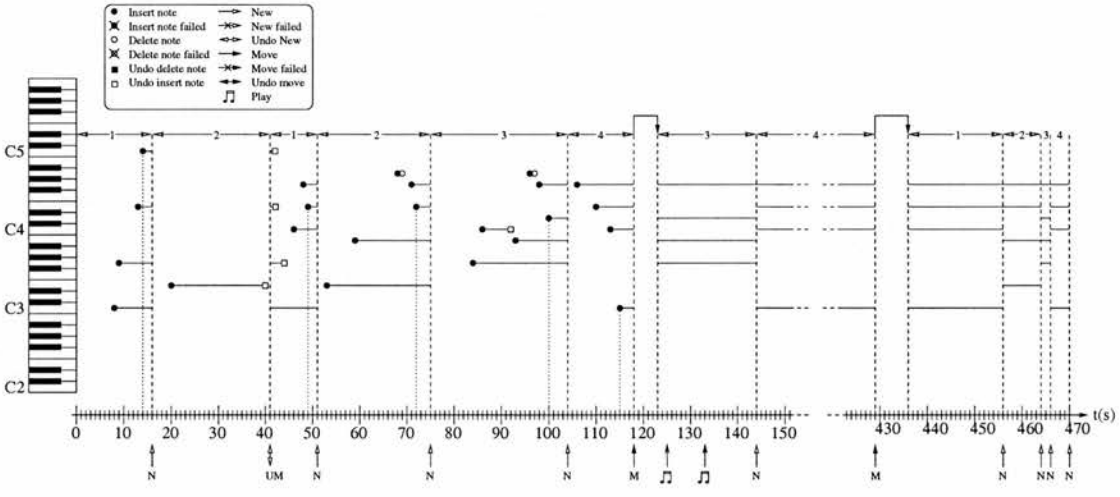
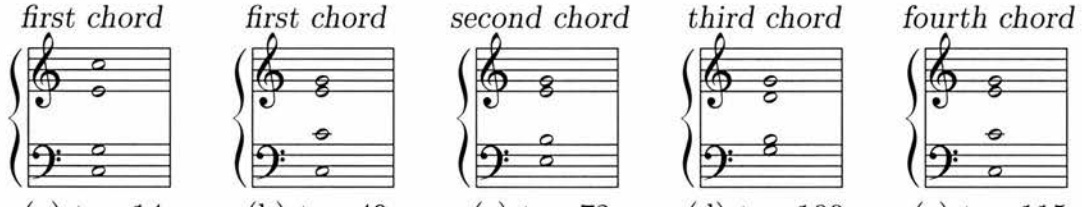


Figure 6.10: Task 4 action diagram for evaluator A



(a) t = 14s (b) t = 49s (c) t = 72s (d) t = 100s (e) t = 115s

Figure 6.11: Task 4 chords constructed by evaluator A

Chord	Time	Action	Comments	Interpretation
1	8	Insert C_3	first note	Insert
	9	Insert G_3	second note	Insert
	13	Insert E_4	third note	Insert
	14	Insert C_5	fourth note (Figure 6.11(a))	Insert
	16	New	chord 1 accepted	New
2	20	Insert E_3	first note	Insert
	40	Undo Insert E_3	remove first note	Undo
	41	Undo New	chord 1 re-selected	Undo
1	42	Delete C_5	remove fourth note	Delete
	42	Delete E_4	remove third note	Delete
	44	Delete G_3	remove second note	Delete
	46	Insert C_4	second note	Insert
	48	Insert G_4	third note	Insert
	49	Insert E_4	fourth note (Figure 6.11(b))	Insert
	51	New	chord 1 accepted	New
2	53	Insert E_3	second note	Insert
	59	Insert B_3	third note	Insert
	68	Insert A_4	non-chord note	Slip
	69	Delete A_4	remove wrong note	Delete
	71	Insert G_4	insert third note	Insert
	72	Insert E_4	fourth note (Figure 6.11(c))	Insert
	75	New	chord 2 accepted	New
3	83	Insert G_3	first note	Insert
	86	Insert C_4	non-chord note	Slip
	92	Undo Insert C_4	remove wrong note	Undo Insert
	93	Insert B_3	second note	Insert
	96	Insert A_4	non-chord note	Slip
	97	Delete A_4	remove wrong note	Delete
	98	Insert G_4	third note	Insert

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Chord	Time	Action	Comments	Interpretation
3	100	Insert D_4	fourth note (Figure 6.11(d))	Insert
	104	New	chord 3 accepted	New
4	106	Insert G_4	first note	Insert
	110	Insert E_4	second note	Insert
	113	Insert C_4	third note	Insert
	115	Insert C_3	fourth note	Insert
	118	Move_a	chord 4 accepted	Move_a
3	123	Move_b	Chord 3 selected	Move_b
	125	Play	sequence reproduced	Play
	133	Play	sequence reproduced	Play
	144	New	chord 3 accepted	New
4	429	Move_a	chord 4 accepted	Move_a
1	436	Move_b	chord 1 selected	Move_b
	456	New	chord 1 accepted	New
2	464	New	chord 2 accepted	New
3	466	New	chord 3 accepted	New
4	470	New	chord 4 accepted	New

Table 6.8: Actions from evaluator A on task 4

The sequence was then played twice at 125s and 133s, and the observer started to interview the evaluator, after suggesting to him that he finish the task. During the interview the evaluator pressed a couple of times the "New" and "Move" buttons, changing the focused chord, and the task was finished at 470s.

Table 6.9 shows a summary of the actions on the interface during task 4, which are shown in the diagram in Figure 6.10. Table 6.8 shows an analysis of the actions.

Action	Intentional					Slip
	Insert	Delete	Undo	New	Move	Insert
Number	20	5	3	9	2	3
Total	39					3

Table 6.9: Summary of the actions from evaluator A on task 4

6.3.2 Evaluator B

Evaluator B is a professional musician with Bachelors and a Master's degree in Music and three diplomas. He has experience in the teaching of harmony and in the use of musical notators but not in the use of musical sequencers. He does not classify himself as a composer, but he does have his own "very short choral pieces".

Evaluator B found the insertion and deletion mechanisms of the interface intuitive and very easy to use, and he thinks the target group would find the same "because most people are very familiar with computers, generally so using the mouse is quite natural". He said he preferred to use the right mouse button instead of the "Undo" button to delete previously inserted notes. He found the focus navigation mechanism very easy to use, although he was slightly confused by the term "New Focus".

When asked about possible improvements in the interface he made the following suggestions:

- change the button's name from "New Focus" to "Next Chord";
- present the current feedback information in bold, and the old information in lighter font in order to drawn the user's attention to the current instruction;
- provide more meaningful information as a feedback;
- provide better balancing between the voices, as he felt the top voice of the chord was not as loud as the rest of it.

6.3.2.1 Task 1

Figure 6.12 depicts the actions from evaluator A on the interface while engaged in the task of constructing a C-major chord. After inserting the first note at 84s,

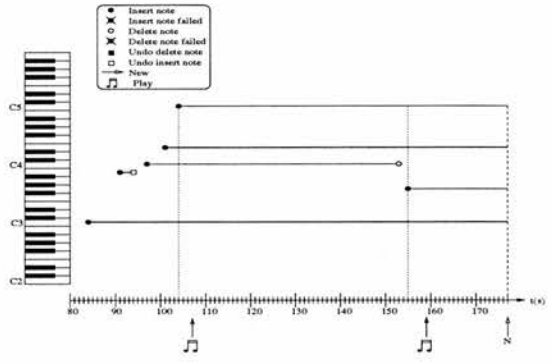


Figure 6.12: Task 1 action diagram for evaluator B

he inserted at 91s, apparently by mistake ("Oops."), a note that was not part of the chord. The note was removed through the "Undo" mechanism and the other three notes that make the chord in Figure 6.13(a) were inserted just after. After playing the chord, the evaluator realised that it did not have the fifth and, following suggestions from the observer about how to delete notes ("*right button, you can delete*"[6]), he used the mouse buttons to modify it to the chord shown in Fig 6.13(b), which was accepted by the interface when the evaluator pressed the "Next Exercise" button at 177s.

(a) t = 104s (b) t = 155s

Figure 6.13: Task 1 chords constructed by evaluator B

[6]References to what the observer said during the interaction will appear in double quotes within parentheses from now on. An *italic* typeface is used to differentiate from references to what was said by the evaluator (see footnote at page 89). The full transcriptions of the interactions can be found in Appendix A

Table 6.10 gives an interpretation for the actions from the evaluator on the task according to the description of the interaction on the previous paragraph, while Table 6.11 gives a summary of the intentional actions and slips.

Time	Action	Comments	Interpretation
84	Insert C_3	first note	Insert
91	Insert B_3	non-chord note	Slip
94	Undo Insert B_3	remove wrong note	Undo
97	Insert C_4	second noted	Insert
101	Insert E_4	third note	Insert
104	Insert C_5	fourth note (Figure 6.13(a))	Insert
107	Play	reproduce chord	Play
153	Delete C_4	remove second note	Delete
155	Insert G_3	second note (Figure 6.13(b))	Insert
177	New	chord accepted	New

Table 6.10: Actions from evaluator B on task 1

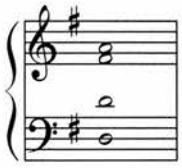
Action	Intentional				Slip
	Insert	Delete	Undo	New	Insert
Number	5	1	1	1	1
Total	8				1

Table 6.11: Summary of the actions from evaluator B on task 1

6.3.2.2 Task 2

Evaluator B constructed at once the close position D-major chord shown in Figure 6.14 without inserting wrong notes. Figure 6.15 show the actions by him while engaged in the task.

Just after constructing the chord, the evaluator listened to it, before pressing the "New Focus" button and having the chord accepted and the task finished.



(a) t = 60s

Figure 6.14: Task 2 chord constructed by evaluator B

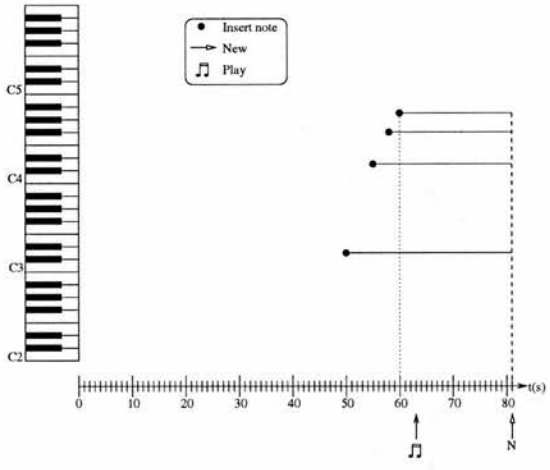


Figure 6.15: Task 2 action diagram for evaluator B

Table 6.12 gives an interpretation for the actions from the evaluator on the task, and Table 6.11 gives a summary of the intentional actions.

Time	Action	Comments	Interpretation
50	Insert D_3	first note	Insert
55	Insert D_4	second note	Insert
58	Insert $F_4^\sharp$	third note	Insert
60	Insert A_4	fourth noted	Insert
63	Play	reproduce chord	Play
81	New	chord accepted	New

Table 6.12: Actions from evaluator B on task 2

Action	Intentional		Slip
	Insert	New	–
Number	4	1	–
Total	5		0

Table 6.13: Summary of the actions from evaluator B on task 2

6.3.2.3 Task 3

Figure 6.16 shows the actions from evaluator B while constructing the sequence I–V–I on the B♭ major key signature. The evaluator started constructing the relative minor chord (g) associated with the given key signature instead of the requested B♭ major chord, as shown in Figure 6.17(a). After asking and receiving

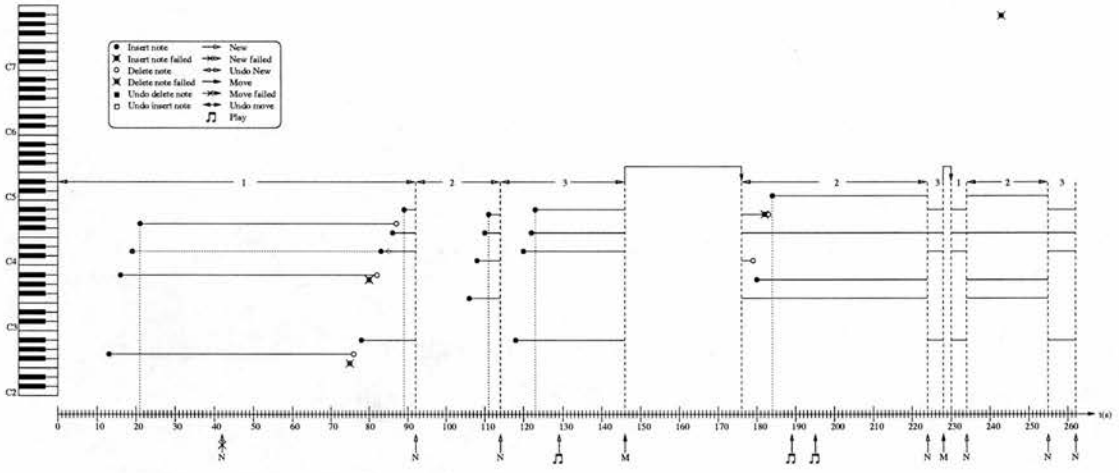
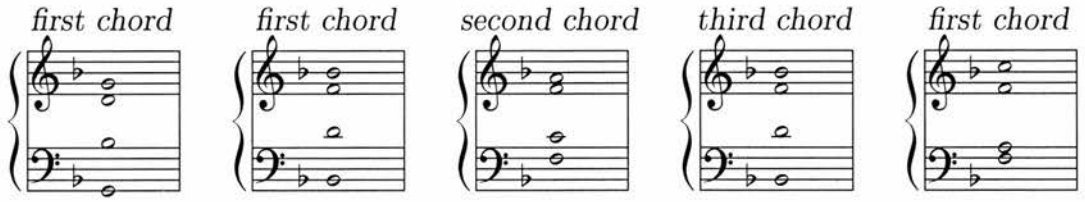


Figure 6.16: Task 3 action diagram for evaluator B

instructions from the observer on how to move to the next chord, he had the chord refused by the interface at 42s and realised he constructed the wrong chord ("Oh, sorry. I've put g minor.")[7].

The g minor chord was converted into the requested B♭ major chord from 76s to 89s with two slips from the evaluator (the mouse pointer was very close, but not on the notes that were deleted just after). The second and third chords of the

[7]the key signature was given only in musical notation as alterations written on the staves, but the capital romans below them left no ambiguity in the requested chords.



(a) t = 21s (b) t = 89s (c) t = 110s (d) t = 123s (e) t = 184s

Figure 6.17: Constructed chords by evaluator B on task 3

sequence were constructed without any slip from 106s to 123s and the sequence was reproduced just after. The observer then asked the evaluator to use the focus mechanism (*"I perhaps suggest you to try to move back the focus, change the chord, because we are trying to evaluate this mechanism"*) in order to modify one of the previous chords. The evaluator chose the second chord, modified it from 179s to 184s and the sequence was reproduced twice. After playing a bit with the focus mechanism, the task was finished at 262s. Table 6.14 gives the interpretation for the actions from the evaluator on the task as described, and Table 6.15 gives a summary of the intentional actions and slips.

Chord	Time	Action	Comments	Interpretation
1	13	Insert G_2	first note	Error
	16	Insert $B\flat_3$	second note	Error
	19	Insert D_4	third note	Error
	21	Insert G_4	fourth note (Figure 6.17(a))	Error
	42	New failed	wrong $B\flat$ major chord	New failed
	75	Delete F_2 failed	no existing note	Slip
	76	Delete G_2	remove first note	Delete
	78	Insert $B\flat_2$	first note	Insert
	80	Delete A_3 failed	no existing note	Slip
	82	Delete $B\flat_3$	remove second note	Delete
	83	Insert D_4	second note	Insert
	85	Delete D_4	remove third note	Delete

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Chord	Time	Action	Comments	Interpretation
1	86	Insert F_4	third note	Insert
	87	Delete G_4	remove fourth note	Delete
	89	Insert $B\flat_4$	fourth note (Figure 6.17(b))	Insert
	92	New	chord 1 accepted	New
2	106	Insert F_3	first note	Insert
	108	Insert C_4	second note	Insert
	110	Insert F_4	third note	Insert
	111	Insert A_4	fourth note (Figure 6.17(c))	Insert
	114	New	chord 2 accepted	New
3	118	Insert $B\flat_2$	first note	Insert
	120	Insert D_4	second note	Insert
	122	Insert F_4	third note	Insert
	123	Insert $B\flat_4$	fourth note (Figure 6.17(d))	Insert
	129	Play	sequence reproduced	Play
	146	Move_a	chord 3 accepted	Move_a
2	176	Move_b	chord 2 selected	Move_b
	179	Delete C_4	remove second note	Delete
	180	Insert A_3	insert second note	Insert
	182	Insert A_5 failed	note already existing	Slip
	183	Delete A_5	remove fourth note	Delete
	184	Insert C_5	fourth note (Figure 6.17(e))	Insert
	189	Play	sequence reproduced	Play
	195	Play	sequence reproduced	Play
	224	New	chord 2 accepted	New
3	228	Move_a	chord 3 accepted	Move_a
1	230	Move_b	chord 1 selected	Move_b
	234	New	chord 1 accepted	New
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Chord	Time	Action	Comments	Interpretation
2	243	Insert $B_7^\flat$ failed	too many notes	Slip
	255	New	chord 2 accepted	New
3	262	New	chord 3 accepted	New

Table 6.14: Actions from evaluator B on task 3

Action	Intentional				Slip (fail)		Error	
	Insert	Delete	New	Move	Insert	Delete	Insert	New fail
Number	14	6	6	2	2	2	4	1
Total	28				4		5	

Table 6.15: Summary of the actions from evaluator B on task 3

6.3.2.4 Task 4

Figure 6.18 show the actions from evaluator B while constructing the sequence I–iii–V–I on the C-major key signature. The evaluator initially constructed, after a couple of slips, the chord shown in Figure 6.19(a). The chord was not accepted by the interface when the "New" button was pressed at 40s, and the observer described briefly that it was because of the octave spacing between the top two voices. The evaluator then substituted, from 97s to 119s, the top three notes of the chord as in Figure 6.19(b), and asked the observer – while trying to insert a fifth note at 131s – what to do next. After pressing the "New" button as instructed by the observer, the new chord was accepted.

The second chord was constructed from 161s to 174s without slips, and was accepted just after the "New" button was pressed at 178s. The third chord was also quickly constructed from 185s to 193s, but was rejected by the interface as its position was undefined (or the fifth was doubled). After some discussion about the validity of the chord, the observer highlighted that the note G_4 from the previous chord was not being kept as required. The evaluator agreed with

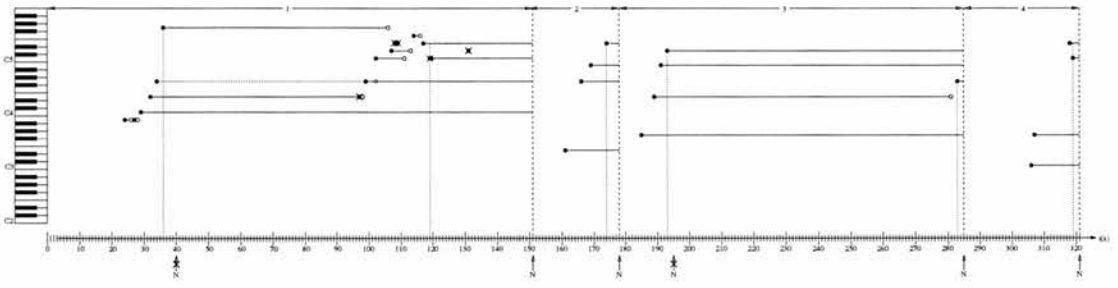
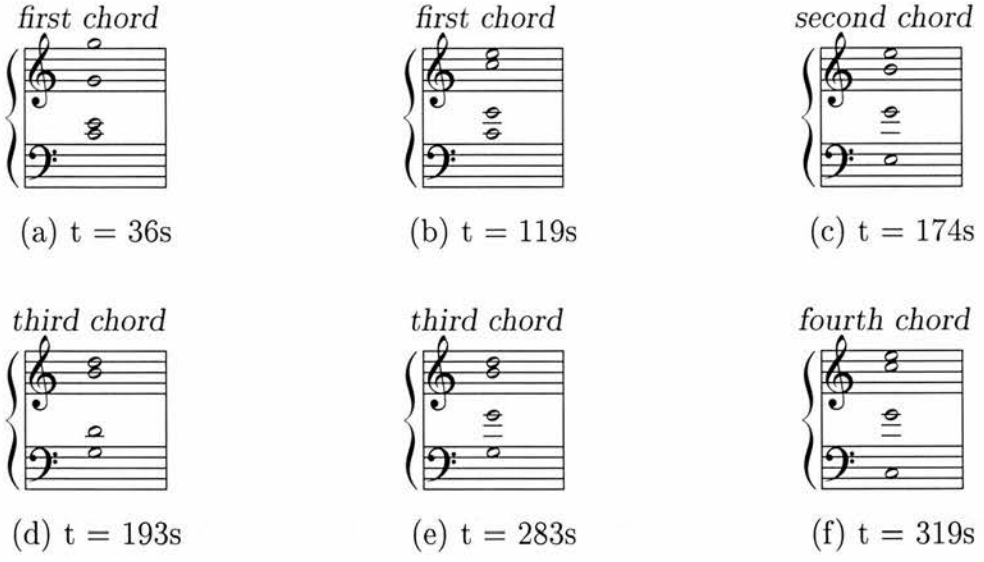


Figure 6.18: Task 4 action diagram for evaluator B



(a) t = 36s (b) t = 119s (c) t = 174s

(d) t = 193s (e) t = 283s (f) t = 319s

Figure 6.19: Constructed chords by evaluator B on task 4

the observation and changed the tenor note from D_4 to G_4 as in Figure 6.19(e). Finally, he constructed the fourth chord from 306s to 319s without slips, which was accepted at 321s and the task was finished.

Table 6.16 gives the interpretation for the actions from the evaluator on the task as described above, and Table 6.17 gives a summary of the intentional actions and slips.

Chord	Time	Action	Comments	Interpretation
1	24	Insert B_3	wrong note	Slip
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Chord	Time	Action	Comments	Interpretation
	26	Delete G_4	remove wrong note	Delete
	27	Insert B_3	wrong note	Slip
	28	Delete G_4	wrong note	Delete
	29	Insert C_4	first note	Insert
	32	Insert E_4	second note	Insert
	34	Insert G_4	third note (treble stave)	Insert
	36	Insert G_5	fourth note (Figure 6.19(a))	Insert
	40	New failed	too large top voices spacing	Slip
	97	Insert E_4 failed	note already existing	Slip
	98	Delete E_4	remove second note	Delete
	99	Insert G_4	second note (bass stave)	Insert
	102	Delete G_4	remove 3^{rd} note (bass stave)	Delete
1	102	Insert C_5	third note	Insert
	106	Delete G_5	remove fourth note	Delete
	107	Insert D_5	wrong fourth note	Slip
	108	Delete E_5 failed	no existing note	Slip
	109	Insert E_5 failed	too many notes	Slip
	111	Delete C_5	remove third note	Slip
	113	Delete D_5	remove wrong fourth note	Delete
	114	Insert F_5	wrong note	Slip
	116	Delete F_5	remove wrong note	Delete
	117	Insert E_5	third note	Insert
	119	Delete C_5 failed	no existing note	Slip
	119	Insert C_5	fourth note (Figure 6.19(b))	Insert
	131	Insert D_5 failed	too many notes	Slip
	151	New	chord 1 accepted	New
	161	Insert E_3	first note	Insert
2	166	Insert G_4	second note	Insert
	169	Insert B_4	third note	Insert
	174	Insert E_5	fourth note (Figure 6.19(c))	Insert

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Chord	Time	Action	Comments	Interpretation
2	178	New	chord 2 accepted	New
3	185	Insert G_3	first note	Insert
	189	Insert D_4	second note	Insert
	191	Insert B_4	third note	Insert
	193	Insert D_5	fourth note (Figure 6.19(d))	Insert
	195	New failed	chord with dubious position	Slip
	281	Delete D_4	remove second note	Delete
	283	Insert G_4	second note (Figure 6.19(e))	Insert
	285	New	chord 3 accepted	New
4	306	Insert C_3	first note	Insert
	307	Insert G_4	second note	Insert
	318	Insert C_5	third note	Insert
	319	Insert E_5	fourth note (Figure 6.19(f))	Insert
	320	New	chord 4 accepted	New

Table 6.16: Actions from evaluator B on task 4

Action	Intentional			Slip		Slip (fail)		
	Insert	Delete	New	Insert	Delete	Insert	Delete	New
Number	21	8	4	4	1	3	2	2
Total	33			12				

Table 6.17: Summary of the actions from evaluator B on task 4

6.3.3 Evaluator C

Evaluator C has a Bachelors degree in Composition by the University of Campinas in São Paulo, Brazil, and he is finishing a Master Degree in Jazz Composition at Napier University in Edinburgh. He has been a professional musician for more

than twenty years, and has been using regularly notation programs for over fifteen years.

He found the insertion and deletion mechanisms easy to use, and he believes the target group would find them obvious. He preferred to use the mouse buttons on canvas rather than using the "Undo" mechanism to insert/delete notes, and he thinks the target group would prefer the same. He was expecting "the software to detect the chord automatically", but after he understood there was a need to press the "New" focus to process the chord he found the focus mechanism easy to use. He found the feedback provided "very accurate".

When asked about possible improvements in the interface, he made the following suggestion:

- provide sound when the insert button is pressed, producing a glissando if the mouse is run around the stave.

6.3.3.1 Task 1

Figure 6.20 presents the actions from evaluator C on the interface while performing task 1, and Figure 6.21 shows the constructed chords during the task. After he constructed the first chord shown in Figure 6.21(a) with one slip and reproduced it twice, the observer suggested he use the "Undo" mechanism, which was used to remove all four inserted notes. The evaluator then tried to reconstruct the chord, which was completed again at 118s, and in this process he made a number of slips which included attempts to remove the top note at 88s and 109s ("What's that?") using the insert button.

The evaluator then decided to modify the top note ("If I put a B here...") in order to get feedback from the interface for a wrong chord, as suggested before in the interaction by the observer (*"You can try to click on the B just for you to get a feedback from a wrong chord of the system."*). He said explicitly he was trying to place the note B, but after some slips he managed[8] to substitute the top note for the note A_4 at 134s, pressed the "New" button, read the feedback

[8]It is interesting to highlight the fact that the evaluator at 130s pressed the mouse buttons 5 times within a second!

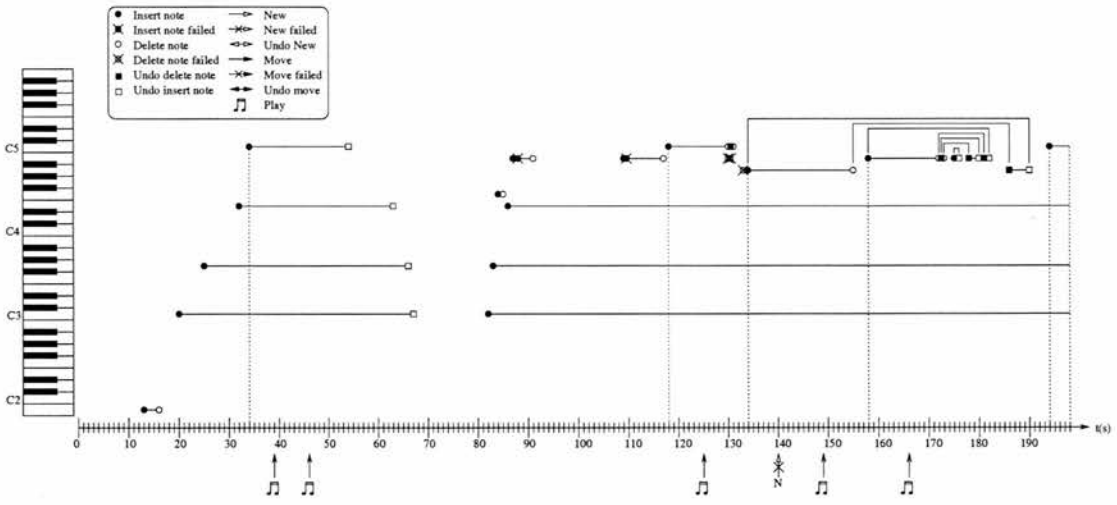
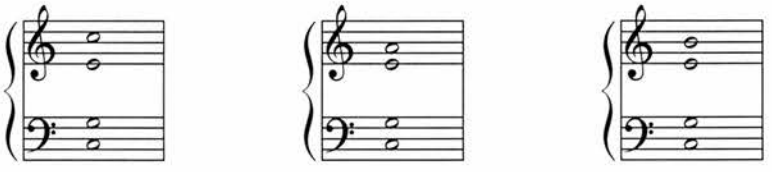


Figure 6.20: Task 1 action diagram for evaluator C



(a) t = 34s, 108s, 194s (b) t = 134s (c) t = 158s

Figure 6.21: Constructed chords by evaluator C on task 1

from the system ("Note A natural in the treble stave is not part of the chord.") and reproduced the chord ("Ok. But I can still hear it."). Then, he deleted the A_4 and substituted it at 158s, now without slips, for the B_4 he was intending to put. Finally, following a suggestion from the observer (*"Try the "Undo" right now, just for you to check one thing. Twice. Try it again."*) he experimented a bit with the "Undo" mechanism, returned the top note to the original C_5, and finished the task pressing the "New" button and received the positive feedback from the interface ("Chord I in open position with the root in the soprano.").

Table 6.18 gives the interpretation for the actions from the evaluator on the task as described above, and Table 6.19 gives a summary of the intentional actions and slips.

Time	Action	Comments	Interpretation
13	Insert B_1	wrong note	Slip
16	Delete B_1	remove wrong note	Delete
20	Insert C_3	first note	Insert
25	Insert G_3	second note	Insert
32	Insert E_4	third note	Insert
34	Insert C_5	fourth note (Figure 6.21(a))	Insert
39	Play	reproduce chord	Play
46	Play	reproduce chord	Play
54	Undo Insert C_5	remove note – practice	Undo
54	Undo Insert E_4	remove note – practice	Undo
54	Undo Insert G_3	remove note – practice	Undo
54	Undo Insert C_3	remove note – practice	Undo
82	Insert C_3	first note	Insert
83	Insert G_3	second note	Insert
84	Insert F_4	wrong note	Slip
85	Delete F_4	remove wrong note	Delete
86	Insert E_4	third note	Insert
87	Insert B_4	wrong note	Slip
88	Insert B_4 failed	note already existing	Slip
91	Delete B_4	remove wrong note	Delete
109	Insert B_4	wrong note	Slip
109	Insert B_4 failed	note already existing	Slip
117	Delete B_4	remove wrong note	Delete
118	Insert C_5	fourth note (Figure 6.23(a)	Insert
125	Play	reproduce chord	Play
130	Delete B_4 failed	no existing note	Slip
130	Delete B_4 failed	no existing note	Slip

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Time	Action	Comments	Interpretation
130	Delete C_5	remove note	Delete
130	Insert C_5	reinsert fourth note (Figure 6.23(a)	Insert
130	Delete C_5	Action taken to modify the chord	Delete
133	Delete A_4 failed	remove note	Slip
134	Insert A_4	wrong note deliberately inserted	Insert
140	New failed	wrong chord – practice	New failed
149	Play	reproduce chord	Play
155	Delete A_4	remove wrong note	Delete
158	Insert B_4	wrong note deliberately inserted	Insert
160	New failed	wrong chord – practice	New failed
166	Play	reproduce chord	Play
172	Delete B_4	remove wrong note	Delete
172	Insert B_4	wrong note	Slip
172	Delete B_4	remove wrong note	Delete
175	Insert B_4	wrong note	Slip
176	Undo Insert B_4	remove wrong note – practice	Undo
178	Undo Delete B_4	reinsert wrong note – practice	Undo
180	Undo Insert B_4	remove wrong note – practice	Undo
81	Undo Delete B_4	reinsert wrong note – practice	Undo
182	Undo Insert B_4	remove wrong note – practice	Undo
184	Undo Delete A_4	reinsert wrong note – practice	Undo
190	Undo Insert A_4	remove wrong note – practice	Undo
194	Insert C_5	fourth note (Figure 6.21(a))	Insert
198	New	chord accepted	New

Table 6.18: Actions from evaluator C on task 1

Action x	Intentional					Slip		
	Insert	Delete	Undo	New	New fail	Insert	Ins fail	Del fail
Number	12	9	11	1	2	6	2	3
Total	35					11		

Table 6.19: Summary of the actions from evaluator C on task 1

6.3.3.2 Task 2

The actions from evaluator C on the interface during task 2 are depicted in Figure 6.22. He started constructing, without slips, the close position G-major chord shown in Figure 6.23(a), instead of the requested D-major chord.

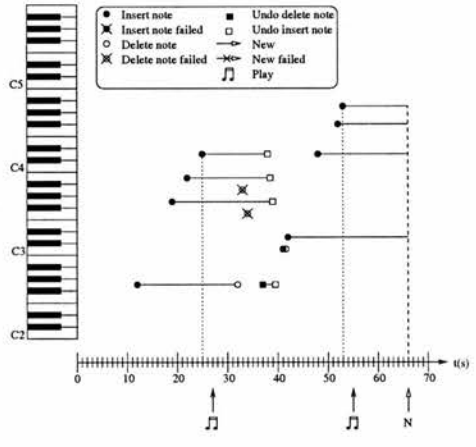
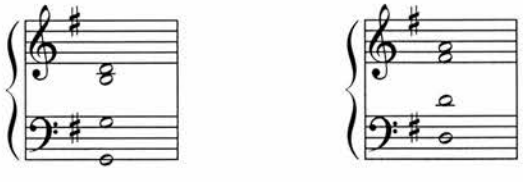


Figure 6.22: Task 2 action diagram for evaluator C



(a) t = 25s (b) t = 53s

Figure 6.23: Constructed chords by evaluator C on task 2

After listening to the chord and realising the chord was not the one requested

("That is not chord I. You want the chord V in G."), the evaluator modified it from 32s to 53s – with a couple of slips – into the D major chord shown in Figure 6.23(b), reproduced it and finished the task at 66s.

Table 6.20 gives the interpretation for the actions from the evaluator on the task as described above, and Table 6.21 gives a summary of the intentional actions and slips.

Time	Action	Comments	Interpretation
12	Insert G_2	first note	Error
19	Insert G_3	second note	Error
22	Insert B_3	third note	Error
25	Insert D_4	fourth note (Figure 6.23(a))	Error
27	Play	reproduce chord	Play
32	Delete G_2	remove first note	Delete
33	Delete A_3 failed	no existing note	Slip
34	Delete $F_3^\sharp$ failed	no existing note	Slip
37	Undo Delete G_2	reinsert first note	Slip
38	Undo Insert D_4	remove first note	Undo Insert
38	Undo Insert B_3	remove third note	Undo Insert
39	Undo Insert G_3	remove second note	Undo Insert
39	Undo Insert G_2	remove first note	Undo Insert
41	Insert C_3	wrong note	Slip
41	Delete C_3	remove wrong note	Delete
42	Insert D_3	first note	Insert
48	Insert D_4	second note	Insert
52	Insert $F_4^\sharp$	third note	Insert
53	Insert D_4	fourth note (Figure 6.23(b))	Insert
55	Play	reproduce chord	Play
66	New	chord accepted	New

Table 6.20: Actions from evaluator C on task 1

Action	Intentional				Slip			Error
	Insert	Delete	Undo	New	Insert	Delete fail	Undo	Insert
Number	4	2	4	1	1	2	1	4
Total	11				4			4

Table 6.21: Summary of the actions from evaluator C on task 2

6.3.3.3 Task 3

The actions from evaluator C on the interface are depicted in Figure 6.24, and the chords constructed are shown in Figure 6.25.

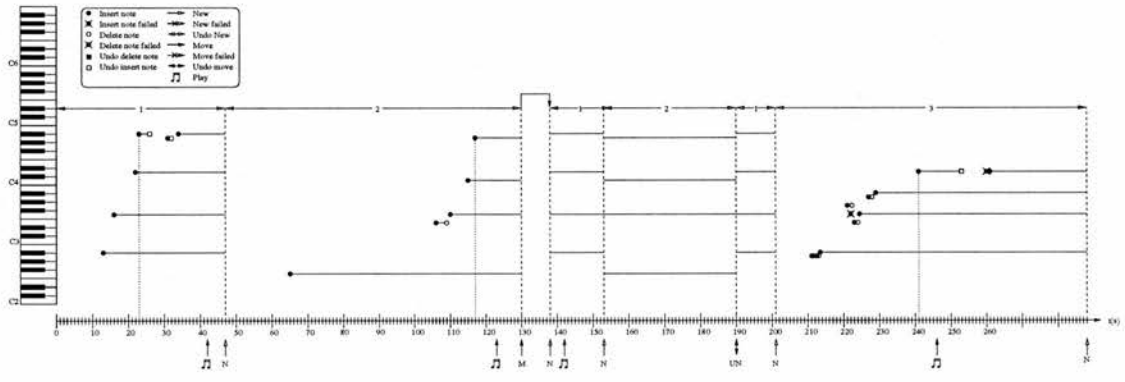
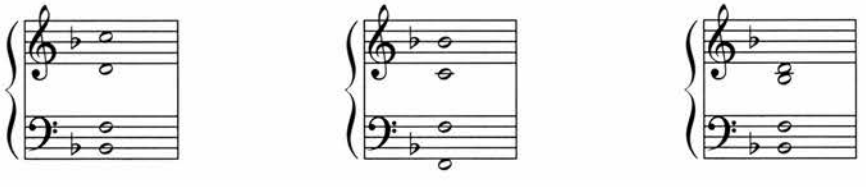


Figure 6.24: Task 3 action diagram for evaluator C



(a) t = 23s (b) t = 117s (b) t = 241s

Figure 6.25: Constructed chords by evaluator C on task 3

The evaluator started constructing the open position $B^{\flat}$ major chord shown in Figure 6.25(a) with only one slip. Then he played it, had it accepted, and

inserted the first note of the second chord. Immediately after there was interference from 65s to 102s which demanded actions from the evaluator[9], as indicated in Figure 6.24. After resuming the task, again he finished the construction of the second chord shown in Figure 6.25(b) with only one slip.

The evaluator then used the focus mechanism to return to the first chord ("That means that I can actually alter the notes here?"), and subsequently to navigate between the two constructed chords. Finally he constructed the third and last chord of the sequence with an unexplained higher amount of slips, played the sequence, removed and restored the top note, and finished the task.

Table 6.22 gives the interpretation for the actions from the evaluator on the task as described above, and Table 6.23 gives a summary of the intentional actions and slips.

Chord	Time	Action	Comments	Interpretation
1	13	Insert $B_2^\flat$	first note	Insert
	16	Insert F_3	second note	Insert
	22	Insert D_4	third note	Insert
	23	Insert $B_4^\flat$	fourth note (Figure 6.25(a)	Insert
	26	Undo Insert $B_4^\flat$	remove note – practice	Undo
	31	Insert A_4	wrong note	Slip
	32	Undo Insert A_4	remove wrong note	Undo
	34	Insert $B_4^\flat$	fourth note (Figure 6.25(a)	Insert
	42	Play	reproduce chord	Play
	47	New	chord accepted	New
2	63	Insert F_2	first note	Insert
	106	Insert E_3	wrong note	Slip
	109	Delete E_3	remove wrong note	Delete
	110	Insert F_3	second note	Insert
	115	Insert C_4	third note	Insert

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[9]The evaluator's son entered the room, and got excited about the laptop.

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Chord	Time	Action	Comments	Interpretation
2	117	Insert A_4	fourth note (Figure 6.25(b))	Insert
	123	Play	reproduce sequence	Play
	130	Move_a	chord 2 accepted	Move_a
1	138	Move_b	chord 1 selected	Move_b
	142	Play	reproduce sequence	Play
	153	New	Chord 1 accepted	New
2	172	New	chord 2 accepted	New
3	190	Undo New	chord 2 reselected	Undo
2	201	New	chord 2 accepted	New
3	211	Insert A_2	wrong note	Slip
	211	Delete A_2	remove wrong note	Delete
	212	Insert A_2	wrong note	Slip
	213	Delete A_2	remove wrong note	Delete
	213	Insert $B_2^\flat$	first note	Insert
	221	Insert G_3	wrong note	Slip
	222	Delete F_3 failed	no existing note	Slip
	222	Delete G_3	remove wrong note	Delete
	223	Insert E_3	wrong note	Slip
	224	Delete E_3	remove wrong note	Delete
	224	Insert F_3	second note	Insert
	227	Insert A_3	wrong note	Slip
	228	Delete A_3	remove wrong note	Delete
	229	Insert $B_3^\flat$	third note	Insert
	241	Insert D_4	fourth note (Figure 6.25(c))	Insert
	246	Play	reproduce chord	Play
	253	Undo Insert D_4	remove fourth note	Undo
	260	Delete D_4 failed	no existing note	Slip

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Chord	Time	Action	Comments	Interpretation
3	261	Insert D_4	fourth note (Figure 6.25(c))	Insert
	288	New	chord 3 accepted	New

Table 6.22: Actions from evaluator C on task 3

Action	Intentional					Slip	
	Insert	Delete	Undo	New	Move	Insert	Delete fail
Number	14	6	4	5	1	7	2
Total	30					9	

Table 6.23: Summary of the actions from evaluator C on task 3

6.3.3.4 Task 4

The task 4 action diagram for evaluator C is depicted in Figure 6.26.

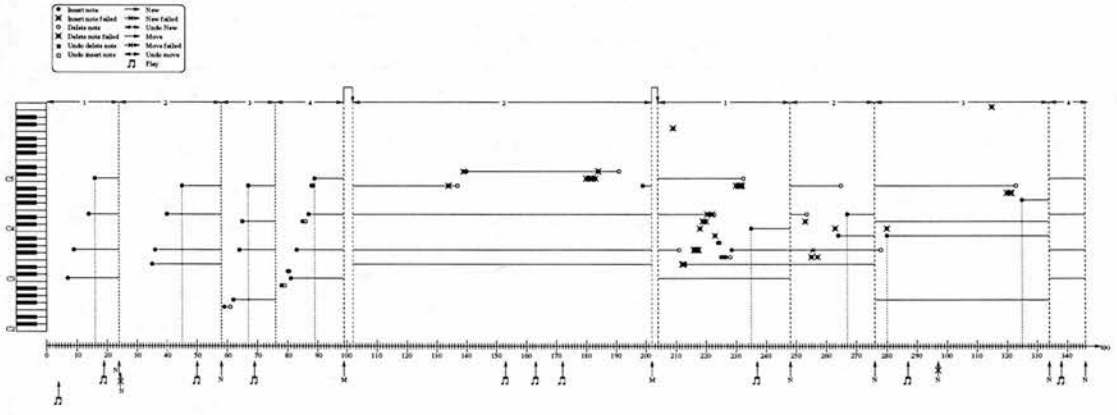

Figure 6.26: Task 4 action diagram for evaluator C

The evaluator constructed the first and second chords in Figure 6.27(a) and (b) without slips, the third chord in Figure 6.27(c) with one slip, and the fourth chord – completed at 89s – with four slips. After the observer suggested using the "Move" button, he moved to the second chord of the sequence and changed

the top note for the seventh, as shown in Figure 6.27(e) and played the sequence at 153s ("Lovely seventh."). As the observer pointed out this chord would not be accepted by the interface (*"We are asking for a third degree chord based on a minor triad, without alterations."*), the evaluator restored the original top note of the chord at 199s and moved to the first chord of the sequence.

At 235s, after a number of slips, he finished the transformation of the original open position first chord in Figure 6.27(a) into the close position chord in Figure 6.27(f). After that, he consistently changed the second and third open position chords into the close position chords shown in Figure 6.27(g) and (h).

Table 6.24 gives the interpretation for the actions from the evaluator on the task as described above, and Table 6.25 gives a summary of the intentional actions and slips.

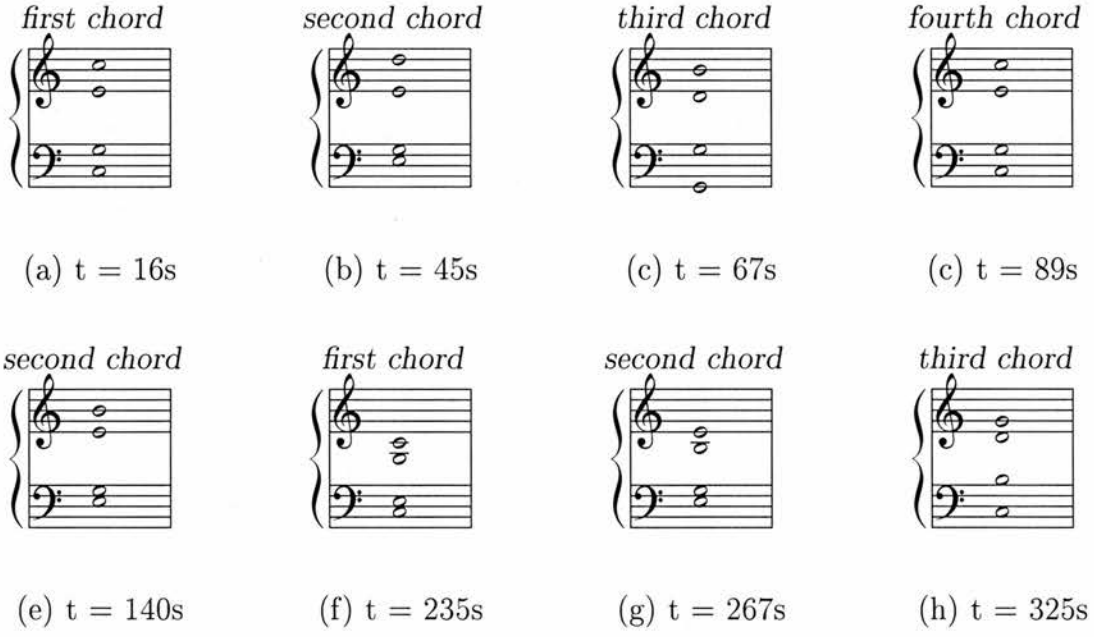

Figure 6.27: Valid sequences of chords constructed by evaluator C on task 4

Chord	Time	Action	Comments	Interpretation
1	7	Insert C_3	first note	Insert
	9	Insert G_3	second note	Insert
	14	Insert E_4	third note	Insert
	16	Insert C_5	fourth note (Figure 6.27(a))	Insert
	19	Play	reproduce chord	Play
	24	New	chord 1 accepted	New
2	24	New failed	double click on button	Slip
	35	Insert E_3	first note	Insert
	36	Insert G_3	second note	Insert
	40	Insert E_4	third note	Insert
	45	Insert B_4	fourth note (Figure 6.27(b))	Insert
	50	Play	reproduce sequence	Play
	58	New	chord 2 accepted	New
3	59	Insert F_2	wrong note	Slip
	61	Delete F_2	remove wrong note	Delete
	62	Insert G_2	first note	Insert
	64	Insert G_3	second note	Insert
	65	Insert D_4	third note	Insert
	67	Insert B_4	fourth note (Figure 6.27(c))	Insert
	69	Play	reproduce sequence	Play
	76	New	chord 3 accepted	New
4	78	Insert D_3	wrong note	Slip
	79	Delete D_3	remove wrong note	Delete
	80	Insert B_2	wrong note	Slip
	80	Delete B_2	remove wrong note	Delete
	81	Insert C_3	first note	Insert
	83	Insert G_3	second note	Insert

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Chord	Time	Action	Comments	Interpretation
4	85	Insert D_4 failed	wrong note	Slip
	86	Delete D_4	remove wrong note	Delete
	87	Insert E_4	third note	Insert
	88	Insert B_4	wrong note	Slip
	88	Delete B_4	remove wrong note	Delete
	89	Insert C_5	fourth note (Figure 6.27(d))	Insert
	99	Move_a	chord 4 accepted	Move_a
2	102	Move_b	chord 2 accepted	Move_b
	134	Insert B_4 failed	note already existing	Slip
	137	Delete B_4	remove fourth note	Delete
	139	Delete D_5 failed	no existing note	Slip
	140	Insert D_5	seventh deliberately inserted (Figure 6.27(e))	Insert
	153	Play	reproduce sequence	Play
	163	Play	reproduce sequence	Play
	172	Play	reproduce sequence	Play
	180	Delete C_5 failed	no existing note	Slip
	181	Delete C_5 failed	no existing note	Slip
	181	Insert C_5 failed	too many notes	Slip
	182	Delete C_5 failed	no existing note	Slip
	183	Insert C_5 failed	too many notes	Slip
	184	Insert D_5 failed	note already existing	Slip
	191	Delete D_5	remove fourth note	Delete
	199	Insert B_4	fourth note (Figure 6.27(b))	Insert
	202	Move_a	chord 2 accepted	Move_a
1	204	Move_b	chord 1 selected	Move_b
	207	Insert F_3 failed	too many notes	Slip
	209	Insert C_6 failed	too many notes	Slip

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Chord	Time	Action	Comments	Interpretation
	211	Delete G_3	remove second note	Delete
	212	Delete E_3 failed	no existing note	Slip
	212	Delete E_3 failed	no existing note	Slip
	213	Insert E_3	second note	Insert
	216	Insert G_3 failed	too many notes	Slip
	216	Delete G_3 failed	no existing noted	Slip
	217	Insert G_3 failed	too many notes	Slip
	217	Insert G_3 failed	too many notes	Slip
	218	Insert C_4 failed	too many notes	Slip
	219	Insert D_4 failed	too many notes	Slip
	220	Delete D_4 failed	no existing note	Slip
	220	Insert E_4 failed	note already existing	Slip
	222	Insert E_4 failed	note already existing	Slip
1	223	Delete B_3 failed	no existing note	Slip
	224	Insert A_3	wrong note	Slip
	224	Delete A_3	remove wrong note	Delete
	225	Insert F_3	wrong note	Slip
	226	Delete F_3	remove wrong note	Delete
	226	Insert F_3	wrong note	Slip
	227	Delete G_3 failed	no existing note	Slip
	228	Insert G_3	third note	Insert
	230	Delete B_4 failed	no existing note	Slip
	231	Insert B_4 failed	too many notes	Slip
	231	Delete B_4 failed	no existing note	Slip
	232	Delete B_4 failed	no existing note	Slip
	232	Delete C_5	remove fourth note	Delete
	235	Insert C_4	fourth note (Figure 6.27(f))	Insert
	237	Play	reproduce sequence	Play

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Chord	Time	Action	Comments	Interpretation
1	248	New	chord 1 accepted	New
2	253	Delete D_4 failed	no existing note	Slip
	253	Delete E_4	remove third note	Delete
	255	Delete F_3 failed	no existing note	Slip
	255	Delete G_3 failed	no existing note (treble)	Slip
	257	Delete F_3 failed	no existing note	Slip
	263	Delete C_4 failed	no existing note	Slip
	264	Insert B_3	third note	Insert
	265	Delete B_4	remove fourth note	Delete
	267	Insert E_4	fourth note (Figure 6.27(g))	Insert
	276	New	chord 2 accepted	New
3	278	Delete G_3	remove second note	Delete
	280	Delete C_4 failed	no existing note	Slip
	280	Insert B_3	second note	Insert
	287	Play	reproduce chord	Play
	297	New failed	chord with dubious position	Slip
	315	Insert F_6 failed	too many notes	Slip
	320	Delete A_4 failed	no existing note	Slip
	321	Delete A_4 failed	no existing note	Slip
	321	Insert A_4 failed	note already existing	Slip
	323	Delete B_4	remove fourth note	Delete
	325	Insert G_4	fourth note (Figure 6.27(h))	Insert
	334	New	chord 3 accepted	New
4	338	Play	reproduce sequence	Play
	346	New	chord 4 accepted	New

Table 6.24: Actions from evaluator C on task 4

Action	Intentional					Slip			
	Ins	Del	Undo	New	Move	Ins	Ins fail	Del fail	New fail
Number	25	15	–	7	2	7	17	21	2
Total	49					47			

Table 6.25: Summary of the actions from evaluator C on task 4

6.4 Analysis of the Results

This section provides an analysis of the interactions taking into account the questions presented in Section 6.1.5. Even though a small sample (3 participants) was employed, in addition to the common music teaching experience, it covers three different musical backgrounds: the composer/researcher on music cognition, the classical performer, and the jazz performer and composer. This could partially explain the different modes of engagement adopted by the evaluators regarding the use of the interface. In this respect, the audio and video evidence helped in identifying actions on the categories of 'intentional', 'slip', 'fail', or even 'intentional fail', adopted in this analysis. However, these categories are not so distinct because of the different degrees of engagement of the evaluators allowed by the interface, and should not be considered as general categories for actions.

1. **Can the user insert notes, using the left button of the mouse within the rectangles, to construct a chord?**
   All evaluators said they found very easy to insert notes using the left button of the mouse. In different degrees, they were able to use the insert mechanism to put notes where they were intending to, as can be observed by a significantly higher number of intentional insert actions when compared to slips or fails as shown in Table 6.26. This is not completely true for evaluator C because he explored the interface mechanisms[10] more than the other evaluators, and as a consequence the number of slips and fails was higher when compared to the other evaluators.

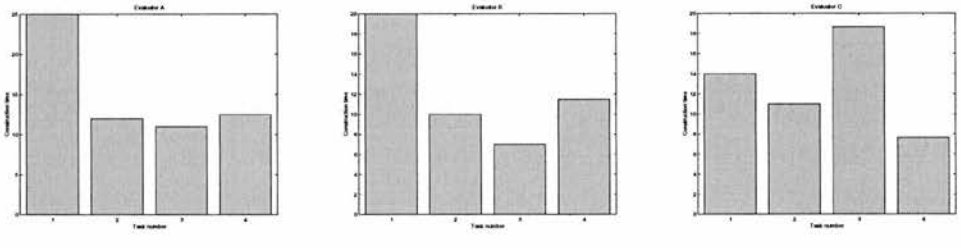
[10]evaluator C was the only evaluator to modify all four chords in task 4 consistently.

Insert	Evaluator A				Evaluator B				Evaluator C			
	T1	T2	T3	T4	T1	T2	T3	T4	T1	T2	T3	T4
Intentional	8	6	18	20	5	4	14	21	12	4	14	25
Slip	1	2	–	3	1	–	–	4	6	1	7	7
Fail	3	2	3	–	–	–	2	3	2	–	–	17
Error	–	–	–	–	–	–	4	–	–	4	–	–

Table 6.26: Insert actions from the evaluators

The errors in the table are in fact intentional actions that correspond to conceptual errors, where the evaluators misunderstood which chord was being requested at the moment, and they deliberately constructed a different chord.

Another indicator that the evaluators felt comfortable with the insertion mechanism is given in Figure 6.28, where we can note that the value of the mean construction time per chord for the evaluators were very close to each other, and below 20s.



mean time = 15.125s mean time = 12.125s mean time = 12.83s

Figure 6.28: Chord construction time

2. **Can the user delete notes using the right button of the mouse on an inserted note ?**

   All evaluators said they found very easy to delete notes using the right button of the mouse. Most actions on the right button of the mouse were intended to remove wrong notes or to modify notes in a chord. As the delete

mechanism demands a note to be clicked on, most unintentional actions were due to right clicking on a non existing note, usually next to a note deleted just after the action. As can be seen in Table 6.27, evaluator C presented the highest number of unintentional actions, which can be explained again by the fact that he was the evaluator who explored the most the mechanisms of the interface.

Delete	Evaluator A				Evaluator B				Evaluator C			
	T1	T2	T3	T4	T1	T2	T3	T4	T1	T2	T3	T4
Intentional	2	1	4	5	1	–	6	8	9	2	6	15
Slip	–	–	–	–	–	–	2	1	–	–	–	–
Fail	–	–	–	–	–	–	–	2	3	2	2	21

Table 6.27: Delete actions from the evaluators

3. **Can the user distinguish between "Undoing" an insertion of a note and "Deleting" a note or does this cause confusion?**

   All the evaluators said that they not only understood the difference, but also that they preferred to use the right button of the mouse to delete an existing note than the "Undo" button as it can be seen through a comparison between Table 6.27, which present all "Delete" actions from the evaluators, and Table 6.28, which present all "Undo Insert" actions from the evaluators.

	Evaluator A				Evaluator B				Evaluator C			
	T1	T2	T3	T4	T1	T2	T3	T4	T1	T2	T3	T4
Undo Insert	3	4	2	2	1	–	–	–	8	4	3	–

Table 6.28: Undo Insert actions from the evaluators

Evaluator A highlighted the fact that these actions usually are within different contexts: "If you put something in the wrong place then it's easy to remove it instantly (using the mouse button), but if you put all the notes

in and you want to change what you have done, then "Undo" is easier". Evaluator B said that "to use the "Undo" (button) puts an extra step into the thing, and if you use the mouse you don't have to".

4. **Can the user distinguish between "Undoing" a deletion of a note and "Inserting" a note or do this cause confusion?**

   All evaluators said they understood the difference between the actions. Evaluator B didn't use the "Undo" button to insert a deleted note, and Evaluator C said that he used it just for an experimental purpose but he wouldn't use it normally. Evaluator A used it only once, as shown in Table 6.29, and he said that "the Undo button is quite a common occurrence on other software, like a Back button in a Web browser or the Edit or Undo buttons in several music packages". He continues saying that "the idea is just kind of reversing back through things you have recently done. It's quite common".

	Evaluator A				Evaluator B				Evaluator C			
	T1	T2	T3	T4	T1	T2	T3	T4	T1	T2	T3	T4
Undo Delete	–	1	–	–	–	–	–	–	3	1	–	–

Table 6.29: Undo Delete actions from the evaluators

5. **Can the user move on to the next chord by clicking the "New Focus" button?**

   Evaluators A and B found it very easy to use the "New Focus" button. Evaluator C said he was expecting the software to automatically detect the chord but, after he understood there was a need to press the "New" button to process the current chord and move to the next one, he found it easy to use the mechanism. Table 6.30 shows all the actions from the evaluators on the "New" button.

New	Evaluator A				Evaluator B				Evaluator C			
	T1	T2	T3	T4	T1	T2	T3	T4	T1	T2	T3	T4
Intentional	1	1	3	9	1	1	6	4	1	1	5	7
Intentional fail	–	–	–	–	–	–	–	–	2	–	–	–
Fail	–	–	2	–	–	–	–	2	–	–	–	2

Table 6.30: New Focus actions from the evaluators

6. **Given a partially constructed sequence of chords, can the user use the "Move Focus" button to go back to a previous chord and change its notes?**

   Evaluator B said it was very easy to change notes, and evaluators A and C said it was easy to change notes. Evaluator C was the one who explored most the "Move" mechanism and, differently from the other evaluators, he did changed positions for all four chords of task 4. Table 6.31 shows all the actions from the evaluators on the "Move" button.

Move Focus	Evaluator A		Evaluator B		Evaluator C	
	T3	T4	T3	T4	T3	T4
Intentional	3	2	2	–	1	2
Fail	2	–	–	–	–	–

Table 6.31: Move Focus actions from the evaluators

7. **Given a partially constructed sequence of chords, can the user use the "New Focus" button to move forward to the chord immediately to the right in relationship to the current one (if the current chord is not the rightmost worked chord)?**

   After the evaluators moved back in the sequence through using the "Move" button, they preferred moving forward using the "New" button, as it can be seen in Tables 6.30 and 6.31.

8. **Given a partial constructed sequence of chords, can the evaluators use the "Move Focus" button to move forward to a previously worked chord (if the current chord is not the rightmost worked chord)?**

   As mentioned in the previous item, there was a preference from all evaluators to move forward using the "New" button. However, evaluator A used the "Move" button to move forward in the sequence during task 3, at 227s.

6.5 Summary

The evaluation study described in this chapter has demonstrated that all expert evaluators were able to understand and operate, to different extents, the mechanisms incorporated into the prototype human-computer interface described in Chapter 5, which embodied Schoenberg's principles for chord construction, and some of his pedagogical requirements (see requirements 1 to 4 in § 1.4.5).

Amongst the changes suggested by the evaluators to our interface, the following ones were considered and incorporated into the environment, built on top of the interface, described in Chapter 7:

- change the name of the <New> Focus button from <New> to <Next>;
- change the cursor shape to help the user in the identification of a line or space in the musical canvas;
- enlarge the font size used for the feedback from the system.

Other changes not explicitly mentioned by the evaluators were also made to the interface, aiming to provide students with information as clearly and unambiguously as possible. The next chapter describes these changes and introduces the design of the Learning Environment.

Chapter 7

Design of the Learning Environment

This chapter begins with a description of the modifications made to the human-computer interface designed in Chapter 5, driven by the results of the evaluation study in Chapter 6. The design of our prototype Learning Environment, to be used in the evaluation study in Chapter 8, is then presented. Finally, a description of the exercises and topics of the implemented lessons is given.

7.1 Environment Interface

Some of the suggestions given by the evaluators in the study in Chapter 6 have been incorporated into the human-computer interface, to improve its usability. The changes described in this section are organised with respect to the main aspects of the interface (see Figure 6.1): the musical canvas, the buttons, the menus and the feedback areas.

7.1.1 Musical Canvas

Figure 7.1 shows the original version of the interface's musical canvas. A description of the changes that were made to the original musical canvas described in Chapter 5 is as follows:

- when within one of the focused rectangles, the mouse cursor changes its arrow-head between empty and filled depending whether it is positioned

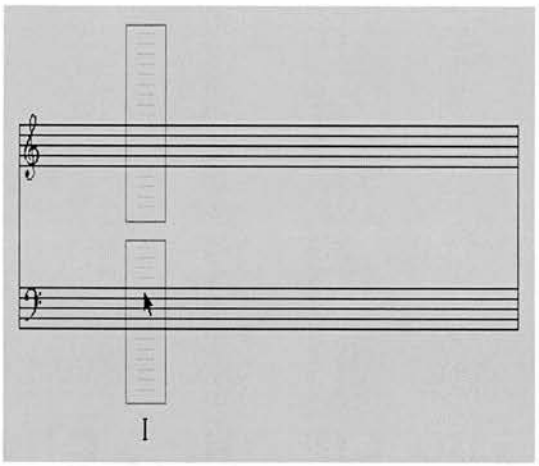
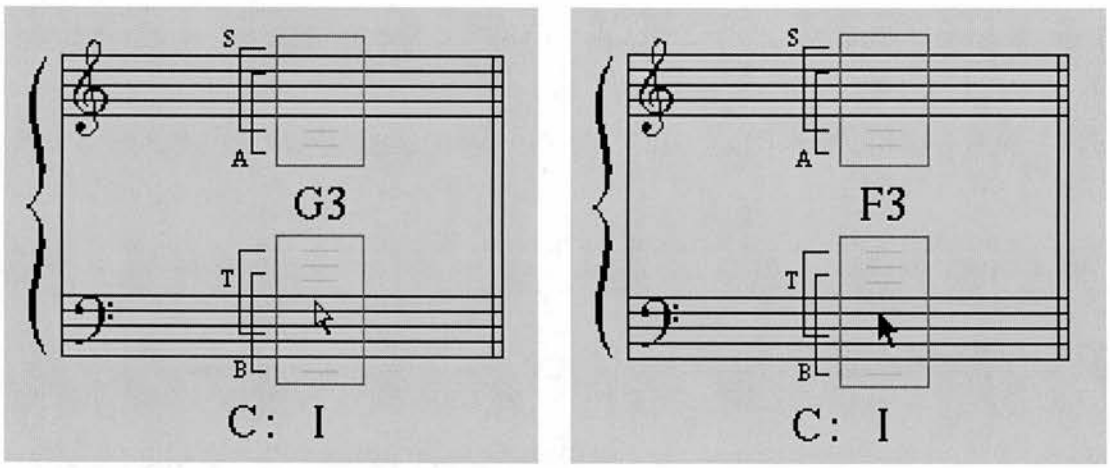


Figure 7.1: The original version of the musical canvas



(a) Cursor on a space of a stave (b) Cursor on a line of a stave

Figure 7.2: The environment's musical canvas

over a space or line of a stave, respectively (see Figure 7.2);

- when within one of the focus rectangles, the name and octave of the note over which the mouse cursor is positioned is presented between the staves[1];
- an indication of the valid range for each voice is presented[2];

[1]There is an option in the Edit-Preference menu item, shown in Figure 7.5, to switch off the note name display on the musical canvas.

[2]There is an option in the Edit-Preference menu item, shown in Figure 7.5, to switch off the note range display on the musical canvas.

- the horizontal edges of the rectangles, originally allowing the insertion or deletion of notes within the whole piano range (see Figure 6.1), were repositioned in order to prevent the insertion of notes outside the extremes of voice range for each one of the staves. This means that notes cannot be inserted
  - above the soprano range on the treble stave;
  - below the alto range on the treble stave;
  - above the tenor range on the bass stave;
  - below the bass range on the bass stave;
- the key signature is indicated in front of the first chord of the sequence.

7.1.2 Buttons

Figure 7.3 shows the original version of the interface's buttons. The main changes made on the buttons section of the interface are shown in Figure 7.4 and described below:

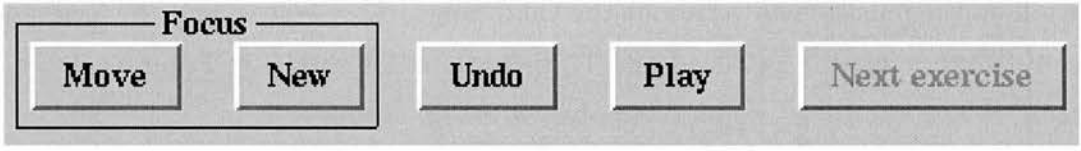


Figure 7.3: The original version of the interface's buttons

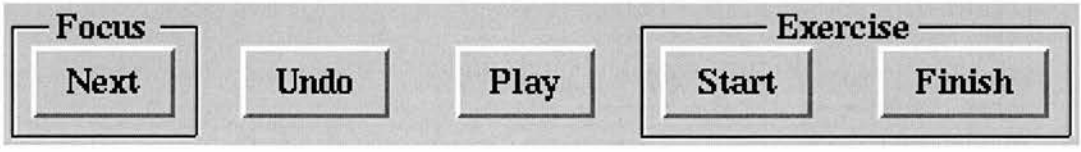


Figure 7.4: The environment's buttons

- the <Move> button was removed from the interface because the results of the usability study in Chapter 6 implied its use was not intuitive. Using

the <Undo> button it is possible to go back to any previous chord in the sequence by reversing previous actions on the musical canvas and uses of the <Next> button;

- <Next> button
  - the name was changed from <New> to <Next> in order to avoid ambiguity in the meaning (evaluator A said that "<New> tends to imply something that is not here rather the <Next>, which implies moving onwards"; the other evaluators also provided very similar comments);
  - its use was restricted to movement to the next chord of the sequence, and the finishing of exercises was not bound to it any longer;
- a <Finish> button was added to allow users unambiguously to finish exercises.

7.1.3 Menus

An option on the Edit–Preference menu allows users to disable the presentation of the note name corresponding to the mouse cursor position. Similarly, the indication on the musical canvas about the valid range of the voices, and the feedback given to users, can be switched off. These options are shown in Figure 7.5.

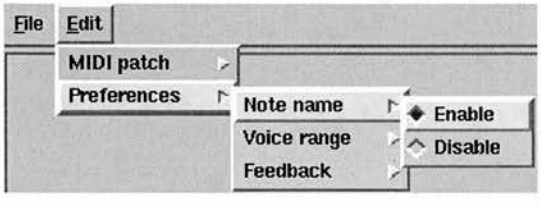


Figure 7.5: The environment's menus

7.1.4 Instructions

Figure 7.6 shows the environment's instructions area, in which the main instructions are given to the student. In the older version of the interface, instructions were originally presented in the same area of the screen as the feedback.

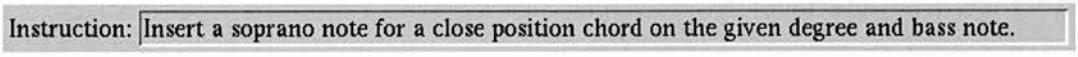


Figure 7.6: The environment's instructions area

7.1.5 Feedback

Figure 7.7 shows the environment's feedback area, in which a chord connection error is being identified (the sixth leap in the bass is not allowed), and a possible solution is being presented

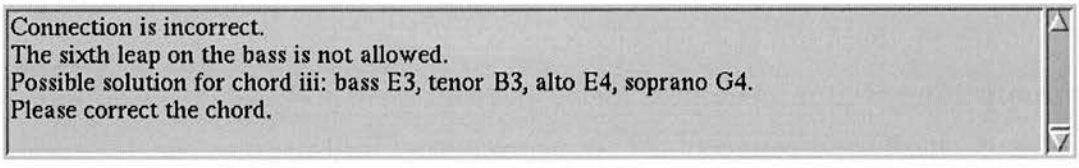


Figure 7.7: The environment's instructions area

7.2 Environment Architecture

The architecture of the learning environment is based on the model that has been used in the development of Intelligent Tutoring Systems (Burns et al., 1991). The high level components of the environment are shown in Figure 7.8 and summarised below.

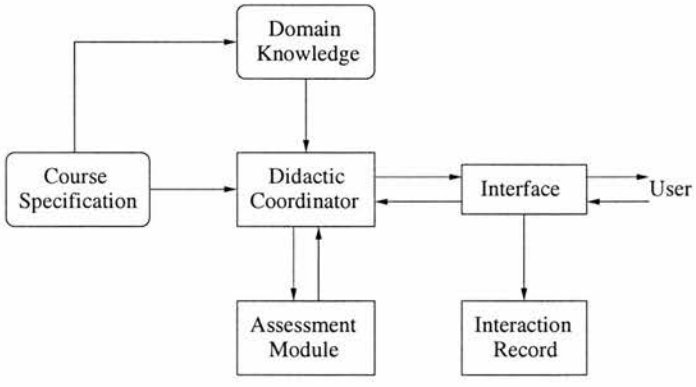


Figure 7.8: The architecture of the learning environment

Interface The interface of the system, described in Chapters 5 and Section 7.1, provides, in addition to music notation and audio output, mouse and keyboard input;

Interaction Record is a record of the actions from the user on the interface and of the operations performed by the system;

Course Specification A logical description of the exercises, topics and modules of the course;

Didactic Coordinator uses information from the assessment module to give students feedback about their solutions and to define the next information to be presented to the student;

Domain Knowledge contains a logical description of acceptable solutions (correct chords and connections) to the exercises. It also stores the description of the incorrect solutions that should be avoided. This description evolves as students progress in the curriculum, as indicated by the connection with the course specification module;

Assessment is a module that compares the student's solution with the correct and incorrect information in the domain knowledge module to inform the didactic planner.

In addition to a logical description of chords as in Section 5.3, the domain knowledge module contains also lists describing chord connections, as exemplified below for all correct connections of open position chords I and iii on the C-major key signature[3]. Figure 7.9 shows these connections in musical notation.

```
array set openconnections {
  C,1,3 {{{{3 1 natural}{3 5 natural}{4 3 natural}{5 1 natural}}
          {{3 3 natural}{3 5 natural}{4 3 natural}{4 7 natural}}}
         {{{3 1 natural}{4 1 natural}{4 5 natural}{5 3 natural}}
          {{3 3 natural}{3 7 natural}{4 5 natural}{5 3 natural}}}
         {{{3 1 natural}{4 3 natural}{5 1 natural}{5 5 natural}}
          {{3 3 natural}{4 3 natural}{4 7 natural}{5 5 natural}}}
        }
```

[3]As in Lesson 2 of the major mode module (see Section 7.4.2).

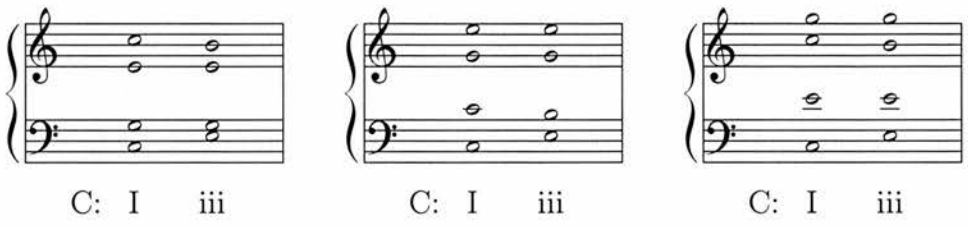


Figure 7.9: Connections of open position chords I and iii on C-major

At each attempt of the user to move the focus to the next position, the assessment module check if the current chord is correct (see Section 5.3), and if its connection with the previous chord is correct. This is done by checking if the "current connection" exists in the list of correct connections. If it does not exist, or if the current chord is not correct, the assessment module passes to the interface a warning message asking the student to rebuild the current chord.

Rules specifying incorrect movements of voices can also be represented in the domain knowledge. Figure 7.10 exemplifies the rule to avoid the leap of a sixth on the bass voice. If the assessment module identifies rules being broken, it passes to the interface a built-in message informing the user what the problem is.

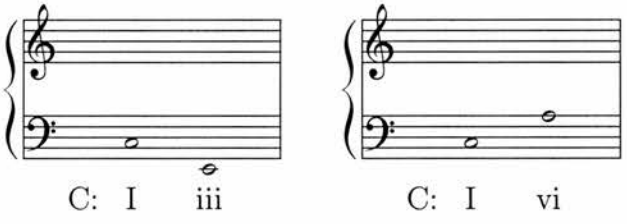


Figure 7.10: Leaps of a sixth on the bass voice should be avoided

7.3 Course Specification

The proposed interpretation of Schoenberg's curriculum is specified in terms of *lessons* and *modules*. A lesson involves a clearly identifiable musical skill (e.g. how

to connect two chords), while a module joins related lessons into broad units that deal with related skills (e.g. major mode). Similar lessons (e.g. how to connect chords having common notes) can appear in different modules and, because of the different contexts on which they appear, they are considered independent. Figure 7.11 shows a standard relationship between these elements, where the modules are:

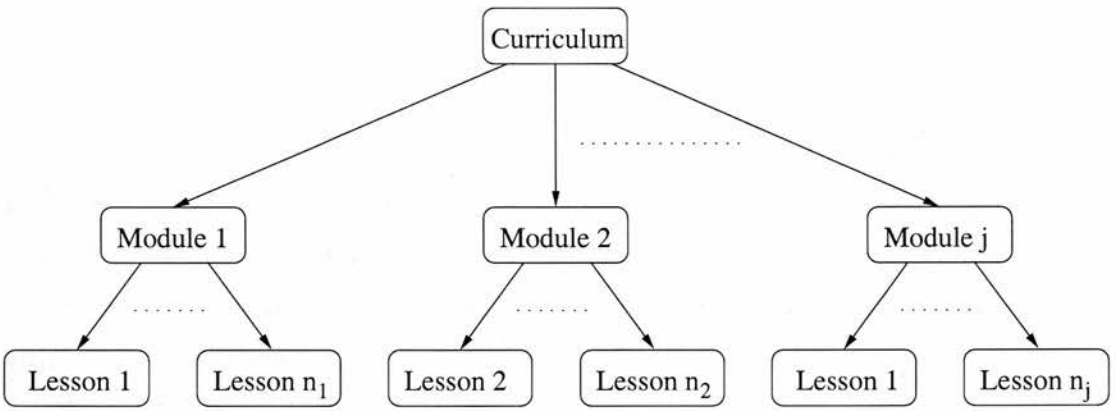


Figure 7.11: Structure of the curriculum

- Module 1: Major Mode;
- Module 2: Minor Mode;
- Module 3: Connection of Chords without Common Tones;
- Module 4: Directions for Good Progressions;
- Module 5: Freer Treatment of VII in Major and Minor;
- Module 6: Modulation;
- Module 7: Secondary Dominants.
- etc.

It is not the aim of the prototype to provide students with the necessary background information regarding a particular lesson or module but to provide a coherent sequencing of exercises according to Schoenberg's parameters. Students must refer to a paper-based version of the background information derived from the book (Schoenberg, 1990), or to the book itself, before interacting with the

environment. For the evaluation study presented in Chapter 8, in addition to annotated copies of the relevant sections of Schoenberg (1990), a hand-out was provided to evaluators (see Appendix B) making the background information[4] explicit for the tasks.

Also, it is not the aim of this thesis to incorporate the whole of Schoenberg's method for teaching harmony into a learning environment but to answer the questions posed in Section 1.5. Even though only major mode materials are being currently delivered by the prototype learning environment, its design can potentially accommodate the necessary expansions – which are in the plans of the author – to fully incorporate the method. The next section describes how module 1 can be expanded into its initial lessons, which are in turn composed of topics associated to particular sub-skills necessary to perform the ultimate tasks.

7.4 Major Mode Module

This module forms the basis for the curriculum, where the procedure for constructing and connecting four-voice chords built around the basic triads from the diatonic major scale is introduced and practiced. The emphasis is on the *law of the shortest way* and on the necessity of keeping the *harmonic link* while connecting chords, except for triads on the seventh degree (vii), which require *preparation* and *resolution* (see Section 4.2.3). Four lessons, incorporating the most important of Schoenberg's principles, were included in the prototype:

- Lesson 1: Constructing Chords;
- Lesson 2: Connecting Chords with Common Tones;
- Lesson 3: Connecting Chords with Common Tones in Small Phrases;
- Lesson 4: The viith Degree.

The other lessons give directions for connecting other chords based on the diatonic major scale, and their decomposition into topics can be made in a similar

[4]Which is a restricted subset of the background information assumed by the evaluators.

way as in the next sections, which provide a description for the lessons implemented in the prototype.

7.4.1 Lesson 1: Construction of Chords

Lesson 1 deals with the procedure for constructing a four-voice chord. The decomposition of the lesson into topics that involving single instructional tasks is based on the steps suggested by Schoenberg to avoid construction errors:

- select the bass note as the root degree;
- select the soprano note;
- complete the alto and tenor voices with the missing triad tones

The steps involve selecting first the bass note, then the soprano note, followed by the completion of the missing triad tones according to the chord position chosen. These steps can be observed in the sequence of topics listed below. Figure 7.12 shows the exercises designed for the evaluation study described in Chapter 8. These exercises are detailed in Appendix B (Figures 1 to 5 on pages 262 to 264).

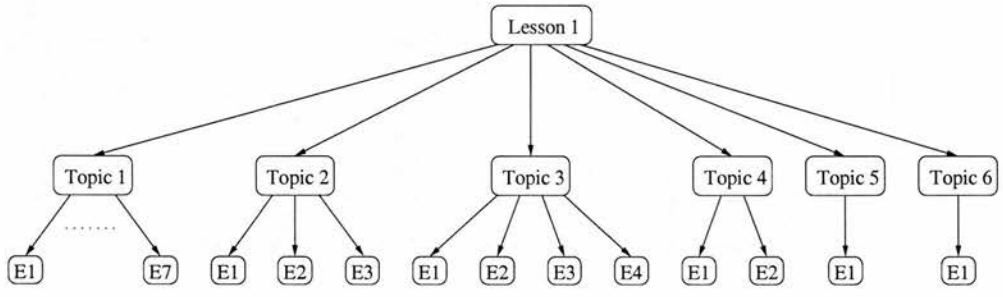


Figure 7.12: Topics and exercises for lesson 1

- Topic 1: Selecting the Bass Voice
- Topic 2: Selecting the Soprano Voice
- Topic 3: Selecting the Alto Voice
- Topic 4: Selecting the Tenor Voice

- Topic 5: Constructing a Close Position Chord
- Topic 6: Constructing an Open Position Chord

7.4.2 Lesson 2: Connection of Chord with Common Tones

Lesson 2 deals with the procedure for connecting two four-voice chords that have common tones. As detailed in Section 4.2.3, these tones must be kept sounding on the same voice (mantaining the *harmonic link*) and the global movement of the top three voices must be as small as possible (*law of the shortest way*). The decomposition of the lesson into topics involving single instructional tasks is based on the steps suggested by Schoenberg to avoid connection errors:

- choose the bass note as the root degree;
- sustain the common tones on the same voices;
- complete the remaining voices with the missing tones in such a way that
  - only the root degree is doubled;
  - the smallest movement of the top three voices is achieved.

The order of these steps is reflected in the order of the topics shown in Figure 7.13 and listed below. The exercises for these topics are presented in Appendix B (Figures 6 and 7 on page 264).

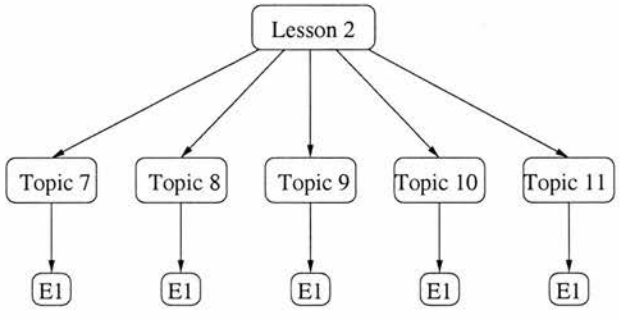


Figure 7.13: Topics and exercises for lesson 2

- Topic 7: Selecting the bass voice for the second chord;

- Topic 8: Selecting the common tone(s) for the second chord;
- Topic 9: Completing the second chord;
- Topic 10: Constructing the Second Chord;
- Topic 11: Constructing both chords.

7.4.3 Lesson 3: Connecting Chords with Common Tones in Small Phrases

Lesson 3 involves the construction of chords with common tones in short phrases presenting chords. The environment is operating on the "discovery mode", in which the student has freedom to select the notes for the first chord in the open or close positions. The focus on the next chord (see Section 5.3.5) would be achieved only when the chord is correct and, for the rest of the sequence, when the connection with the previous chord is also correct. The decomposition of the lesson into topics is listed below. Figure 7.14 shows the exercises, which are detailed in Appendix B (Figures 9 to 15 on pages 265 to 267).

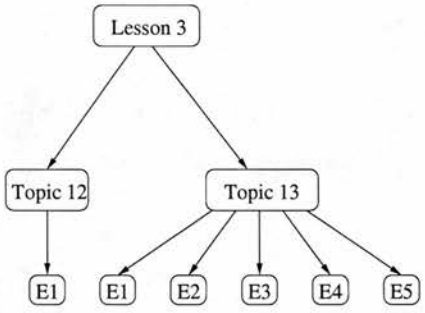


Figure 7.14: Topics and exercises for lesson 3

- Topic 12: Connecting chords in phrases having three chords;
- Topic 13: Connecting Chords in phrases presenting common tones.

7.4.4 Lesson 4: The viith degree

Lesson 4 involves the construction of chords in short phrases presenting a chord on the seventh degree. This chord requires *preparation* and *resolution* as described

is Section 4.2.5. The resolution of its fifth degree is crucial, and the *law of the shortest way* should considered only after satisfactory resolution has been achieved. Lesson 4 consists of a single topic as shown in Figure 7.15, whose exercises are detailed in Appendix B (Figure 16 and 17 on page 267):

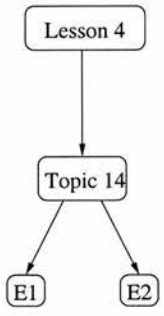


Figure 7.15: Topics and exercises for lesson 4

- Topic 14: Connecting Chords in phrases presenting the viith degree.

7.5 Summary

This chapter has presented the design of our prototype Learning Environment. The modifications made to the original human-computer interface have been described. The environment architecture and the course specification have been introduced, followed by a description of the lessons of the major mode module that were incorporated in the prototype. The next section presents the evaluation study that was carried out to evaluate the prototype Learning Environment.

Chapter 8

Evaluation of the Learning Environment

The previous chapter described how Schoenberg's pedagogy and curriculum, and how the usability study presented in Chapter 6 informed the design of our Learning Environment.

This chapter describes the summative evaluation of the Learning Environment, which took a form of an empirical study, using a methodology similar to the one presented in Chapter 6. The goal of the evaluation was to assess how faithful is the prototype of the learning environment, described in Chapter 7, to the method described in Schoenberg (1990) and how effective a computer based version of the method is in comparison with the book-based version.

8.1 Introduction

The design of the summative evaluation of the learning environment prototype described in this chapter followed the general principles for evaluating intelligent teaching systems identified by Shute & Regian (1993), and presented in Section 6.1. The same principles guided the design of the formative evaluation of the interface prototype detailed in Chapter 6.

This section derives from the general questions presented in Section 1.5 a set of specific questions to be addressed in this evaluation, and details the general methods that were used to address them.

8.1.1 General Questions

The main questions we are trying to answer through this evaluation are posed in Section 1.5, and reproduced here for the reader's convenience:

1. Is it possible to formalise the rules of Schoenberg's harmonic method in such a way that they are amenable for use in a computer-based environment?

2. Is it possible to embody the basic principles of chord construction and connection as specified in Schoenberg's method in such an environment?

3. Can the materials of Schoenberg's method be delivered by a computer-based learning environment so as to explore the full range of activities available in a way appropriate to the method?

4. Is there a satisfactory means by which we can make such formalised materials (see '3' above) potentially accessible to the user?

The formalisation of the principles of Schoenberg's method in Chapter 4 and the design of the prototype environment in Chapter 7 addresses question 1 and partially addresses question 3. Question 2 is partially and positively answered in Chapters 5 and 6 and is further addressed in this chapter along with questions 3 and 4.

The next section describes the general methods used in the evaluation and Section 8.1.3 expands the last three questions above into a more manageable set of specific questions.

8.1.2 General Methods

The evaluation technique used is *certification* (Mark & Greer, 1993), in which competent human teachers judge the adequacy of teaching systems during a summative evaluation[1]. According to McGraw & Harbison-Briggs (1989, p. 303), certification would be "an authoritative endorsement of the correctness of a program". However, as emphasized by Mark & Greer, such an endorsement could

[1]Certification can also be used during formative evaluation to identify strengths and weaknesses of teaching systems aiming to improve their design.

be applied only in situations where the following questions, to which there are still not clear answers, can be properly addressed:

- Which *standards* are appropriate for assessing systems?
- Which *criteria* can be used for evaluating systems and components;
- Is the identification of effective educational programs by humans *accurate*?

In our study, the criterion used to select participants was the subject matter on which subjects were knowledgeable and experienced (see § 8.2.1). In order to invest subjects with enough authority to assess the faithfulness of the prototype of the computer-based learning environment to Schoenberg's harmony teaching method, they were required to read the relevant parts of the text-book (Schoenberg, 1990, pp. 31-52)[2] in advance, before the study was run.

Task-based exercises were presented to evaluators through our environment, and records in the form of dribble files and direct observation of evaluators interacting with the environment were made. A semi-structured interview took place at the end of each interaction aiming to collect the evaluator's overall impression about our environment and how effective a computer based version of the method is in comparison with the literary presentation in Schoenberg (1990). The interview also gathered the experts' opinions about the potential strengths, weaknesses and benefits for the target users of the system.

8.1.3 Specific Questions

This section expands the last three general questions presented in Section 8.1.1 (the first general question was already addressed in Chapters 4 and 7) into a more manageable set of specific questions. The methods used to answer each one of the specific questions are also given.

Using our environment in discovery mode, we may explore **questions 2 and 3**, above, by asking the following related questions:

[2]An additional reading (Schoenberg, 1990, pp. 7-17), with the main pedagogical ideas of the method underlined in it, was also provided to the evaluators.

1. Is the user selecting firstly the bass note for each chord?[3] The methods used to answer this question were observation and analysis of dribble files.

2. Is the second note selected by the user, for the first chord in a sequence, the soprano note?[4] The methods used to answer this question were observation and analysis of dribble files.

3. Is the second note selected by the user, for the second and later chords, a common note to the current and previous chord or the resolution of the dissonance (if present)?[4] The methods used to answer this question were observation and analysis of dribble files.

4. Is the music notation interface appropriate for the method? (Is the interface presenting information using a standard music notation symbology? Are the note insertion and deletion mechanisms, when the mouse cursor is within a focus rectangle, appropriate for the method?) The methods used to answer this question were observation, analysis of dribble files and semi-structured interview.

5. Is the use of the <Next> button, to move to the next chord in a sequence after finishing the construction of the current one, an intuitive way of representing Schoenberg's left-to-right pedagogical constraint? (Does the user find it intuitive to use?) The methods used to answer this question were observation, analysis of dribble files and semi-structured interview responses.

Question 4 (see § 8.1.1) can be expanded as follows:

6. Is the sequencing of topics consistent with the method? The method used to answer this question was semi-structured interview responses.

7. Is the control of user's behaviour appropriate? (Given the sequencing of topics of the environment: (a) is it appropriate to repeat the presentation

[3]These questions refer to the discovery mode of the environment, which does not impose on students restrictions on the order in which the voices are completed for each chord. However, the initial chord construction and chord connection exercises are tailored to induce students to follow Schoenberg's suggested order of assigning notes to voices.

[4]See footnote 3 on page 148.

of exercises which were incorrectly answered?; (b) is it appropriate to move to the next topic when the last exercise of the current topic is correctly answered?) The method used to answer this question was semi-structured interview.

8. Is the didactic feedback given at the end of exercises, and also after chord constructions, helpful for the user in correcting the mistake(s)? (Is the feedback appropriate? Would the feedback provided encourage users to correct their mistakes?) The methods used to answer this question were observation and semi-structured interview.

9. Is Schoenberg's exploration of solutions properly embodied in the prototype? The method used to answer this question was semi-structured interview responses.

Further Pedagogical Questions:

10. Was the design decision of taking away from students the responsibility of choosing the chord sequence to work with[5] beneficial to learning? The method used to answer this question was semi-structured interview.

11. Is it better to leave students responsible for assessing their exercises by themselves, as suggested in Schoenberg's method, rather then receiving didactic feedback after each chord construction? The method used to answer this question was semi-structured interview.

12. Is it better to leave students responsible for getting aural feedback (from a musical instrument) rather than having it readily available as in the prototype? (Is the capability of having immediate aural feedback beneficial to learning?) The method used to answer this question was semi-structured interview.

[5]This decision was made taking into account the fact that this might be a distracting element to beginners. Also, the didactic control of the user's actions in this case is more precise.

8.2 Method

The evaluation was carried out in the form of interaction sessions, one for each evaluator. The results presented in Section 8.3 were derived from the analysis of materials (see § 8.2.2) such as questionnaires and dribble files produced during the interaction, and also from direct observation of the evaluators interacting with the environment. Only the subset of the results involving discovery mode exercises, in which evaluators had freedom to construct sequences of chords, are presented. A semi-structured interview took place at the end of each interaction aiming to collect, amongst other data, the evaluator's overall impression about how faithful was the environment when compared to the literary presentation in Schoenberg (1990).

8.2.1 Participants

As can be seen below, except for the last two participants (evaluators D and E, who took part only in the pilot evaluation session), the participants were expert music teachers with experience in teaching harmony, and henceforth are referred to only as evaluators.

Evaluator A has a degree in Music and a PhD in performance practice, and has been teaching harmony courses for 25 years, initially at St. Andrews University and later on at the University of Edinburgh.

Evaluator B has a degree in Music and a PhD in Music History. He is currently the Head of Department of the Faculty of Music at the University of Edinburgh. He has been teaching harmony for several years, for first and second year undergraduate students, in Edinburgh and previously in Lancaster.

Evaluator C is an organist and conductor with a B. Mus and a M. Mus in Composition from the University of Edinburgh and experience in harmony teaching.

Evaluator D is an amateur acoustic guitar player with knowledge of basic Music Theory, and also a research student in Artificial Intelligence.

Evaluator E is a music cognition researcher deeply involved in chorale harmonisation, and a graduate research student in Artificial Intelligence.

8.2.2 Materials

The materials used in this study are:

prototype version 1.1 of the environment (see section 7.2);

handout made up of two sections (see Appendix B pages 253 and 257):

Theoretical Background intended to provide the evaluators with a summary of the Schoenberg's principles relevant to the part of the curriculum embodied in the learning environment;

The Environment gives a description of the functionality of the environment's mechanisms, and of how to operate them;

Schoenberg's "Theory of Harmony" was made available for consultation during the study. Annotated copies of the relevant sections of the book were given in advance to the evaluators, who were asked to read them before taking part in the study;

dribble files store information about every single action of the user with the interface, along with time stamps. From this file the evaluators' answers to exercises and the constructed sequences can be fully recovered;

semi-structured interview sheet made up of two sections (see Appendix B):

Basic Information intended to collect background information from the evaluator;

Questions intended to collect from the evaluators their overall impression of the environment. Specific questions, addressing the different aspects of the literary presentation of the method as described in Schoenberg (1990), were posed aiming to assess the faithfulness of the features of the environment to Schoenberg's method. These were also designed to

assess the potential benefit of our approach to users, and address the additional pedagogical questions (see § 8.1.3).

mini-disc recording an audio record of everything that was said during the whole session, from the basic information collection to the semi-structure interview. The user interaction was also audio-recorded, with some cue points added live by the observer, aiming to help in the identification – in conjunction with the dribble files – of the evaluator's intentions while solving the exercises.

8.2.3 Procedure

As in the evaluation study of the usability of the interface described in Chapter 6, the study was run individually and separately with each evaluator.

The observer was responsible for setting up the physical environment, for collecting information from the evaluator through a questionnaire and a semi-structured interview, for making direct observation and for providing explanation about the environment during the interaction if needed. These steps are described below:

Initial set up The observer completes logistical preparations before each interaction takes place, performing the following steps:

- check printed materials (handout, observer script, and semi-structured interview sheet);
- start the prototype and make sure the audio level is appropriate;
- position the microphone, connect it to the minidisc recorder, and adjust audio recording level.

Background information The observer collects background information from the evaluator and completes the first section on the semi-structured interview sheet (see Appendix B).

Handout 1 The observer asks the evaluator to read the first section of the handout (Theoretical Background), where a summary of the Schoenberg's principles embodied in the the environment is given. These principles have been presented in advance to the evaluators. The observer highlights the constraints for chord construction represented in the environment to encourage the evaluators not to construct more complex chords than the ones involved in the part of the curriculum embodied in the environment;

Handout 2 The observer asks the evaluator to read the second section of the handout (The Environment), and provides evaluators with a verbal description of the mechanisms to be used during the interaction and the way they should expect the environment to react to their actions;

Environment The observer asks the evaluator to interact with the environment, and provides guidance if needed. The interaction sessions consist of the following parts:

Familiarisation Topics 1 to 4 (see Appendix B, page 261) allow the user to get used to the environment mechanisms and the areas of screen defined by the red rectangles in which insertion and deletion of notes are allowed. The sequencing of topics is consistent with the steps for chord construction suggested by the method;

Interaction After familiarising themselves with the environment, the user continues to interact with it, constructing and connecting chords, following the sequencing of topics suggested by the method;

Interview The observer interviews the evaluator, asking questions from the second section of the Semi-structured Interview Sheet (see AppendixB). Specific questions about the level of difficulty the evaluator experienced while dealing with the interface mechanisms were posed, in addition to more general questions aiming to capture the overall impression of the evaluator about the interface.

8.2.4 Pilot Study

A pilot test of the study was run with participants D and E, before the evaluation was carried out with the harmony teachers. The goals of the pilot evaluation were:

i. to practice the logistical preparation;

ii. to check if the total running time of the evaluation was compatible with the time slot agreed with the harmony teachers;

iii. to check the consistency and clarity of the printed materials, in particular the handout;

iv. to identify potential problems that the environment could present, and to fix them before running the real evaluation.

After running the pilot test sessions it was found that the logistical preparation was convenient and that the total running time for each session was adequate for the participants. The handout was considered by them to be clear and unambiguous[6]. The evaluators made the following observations:

- some instructions provided by the environment were not completely clear, and could lead to misinterpretation;
- some feedback messages could be rephrased to clarify their contents;
- the behaviour of the environment in the discovery mode, for some specific chord sequences, was not completely consistent with the design presented in Chapter 7, with a few incorrect chord connections being accepted as correct.

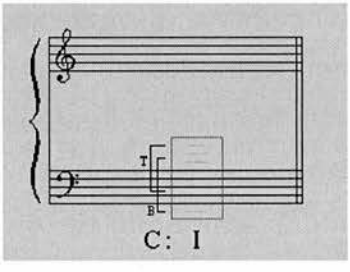
The minor suggestions of rephrasing instructions and feedback messages were incorporated into the environment, and its inconsistent behaviour was identified later on as being associated with a couple of mistakes (typos) in the definition of chord connections.

[6]Very minor alterations were made to the handout and they are shown in Appendix B, page B.

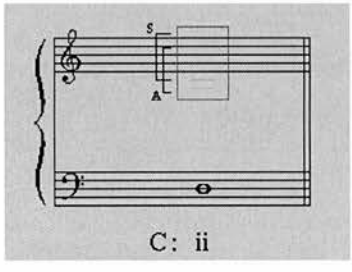
There was a need to run the study twice for each one of the expert harmony teachers (Participants A, B and C) because, as they were asked to challenge the environment, a few situations arose in which the inconsistent behaviour referred above occurred. Therefore, the first evaluation study sessions with participants A, B and C were in fact pilot tests. The few remaining situations of inconsistent behaviour were identified and corrected for the final evaluation study sessions carried out with participants A, B and C.

8.2.5 Exercises

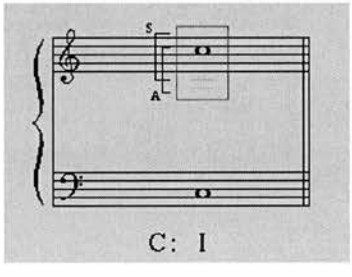
Topics and exercises were presented to the evaluators in a Schoenberg-like sequence: for chord construction, where first the bass note was requested (Figure 8.1(a)), followed by the the soprano note (Figure 8.1(b)), the alto note (Figure 8.1(c)) and the tenor note (Figure 8.1(d)).



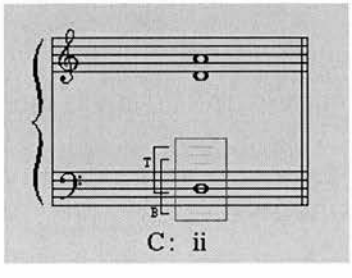
(a) Bass note requested



(b) Soprano note requested



(c) Alto note requested



(d) Tenor note requested

Figure 8.1: Sample exercises

Discovery exercises differ from the exercises above in allowing more freedom of choices as shown in Figure 8.2. However, the environment would only enable the movement of the focus to the next chord if the current chord and the connection

with the previous one is correct.

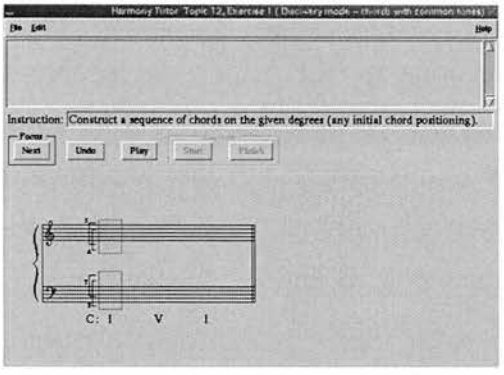


Figure 8.2: Sample discovery mode exercise

8.3 Results

In this section a subset of the results of the study are presented. Only the discovery mode exercises, in which evaluators had freedom to construct sequence of chords, are presented. All other exercises have a single answer that must be given by evaluators in order for the next exercise to be presented, otherwise the same exercise is presented. Each evaluator's solution to the discovery mode exercises in topics 12, 13 and 14 (see Appendix B, page 261) is detailed, and this includes partial sequences for which there were no solution available.

This section also includes the answers of the evaluators to the questions posed after the interaction with the environment took place.

8.3.1 Evaluator A

Personal Background

Evaluator A has been teaching harmony for 25 years, and he has never centred his teaching on any textbook, developing his own teaching material instead. He thinks that the harmonisation of melodies is very important (7/7) for the global assessment of first year harmony students, and that the harmonic analysis of musical pieces from the eighteenth and nineteenth centuries is also very important

(7/7). He believes that it would be feasible to run an undergraduate course centred on Schoenberg (1990), but it would take longer than he is used to teach.

Exercise 12.1 (I – V – I)

In this exercise the evaluator was introduced to the discovery mode, after becoming comfortable in manipulating the environment's mechanisms. The evaluator was asked to familiarise himself with the focus mechanism, introduced in this topic, which enables the movement to the next chord by using the <Next> button, as long as the current chord and connection with the previous chord are correct. The observer highlighted that the <Undo> button can also undo a successful action on the <Next> button. After practicing a little both mechanisms while solving the exercise, evaluator A constructed the sequence depicted in Figure 8.3.

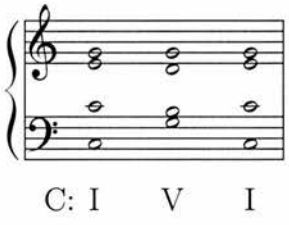


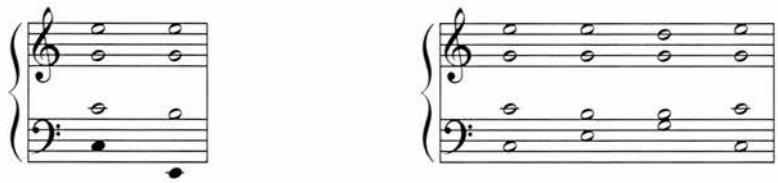
Figure 8.3: Exercise 12.1, evaluator A

Exercise 13.1 (sequence I – iii – V – I)

The observer asked the evaluator to challenge the environment, taking into account Schoenberg's instructions given in advance, which were summarised in the handout (see Appendix B, page 257). After constructing the first chord, the evaluator deliberately constructed a valid second chord, which was not accepted by the environment because there was a sixth interval (forbidden by Schoenberg's rules) in the bass voice, as shown in Figure 8.4(a). The bass note of the chord was corrected and the sequence completed as in Figure 8.4(b).

Exercise 13.2 (sequence I – IV – vi – I)

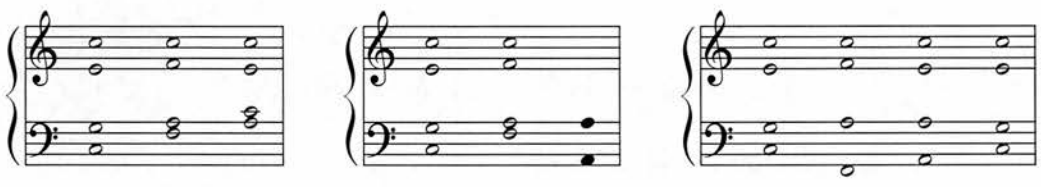
After constructing the first two chords of the sequence as in Figure 8.5(a), evaluator A constructed a chord not conforming to the construction (the doubling tone chosen was the third) and connection instructions (the movement of the individual voices should be smaller), which was therefore refused by the system.



(a) Second chord (b) Final sequence

Figure 8.4: Exercise 13.1, evaluator A

The only two bass note choices for the third chord, shown in Figure 8.5(b) as filled notes, do not conform to Schoenberg's instructions: the bottom note (A_2) corresponds to a non-acceptable sixth leap interval, and the top note (A_3) should be kept sounding in the tenor[7] voice because it is common to both chords. The solution devised by the evaluator was to move back in the sequence and to provide more room between the bass and tenor voices by means of changing the bass note of the second chord to F_2. This enabled the construction of the third chord and the completion of the sequence as in Figure 8.5(c).



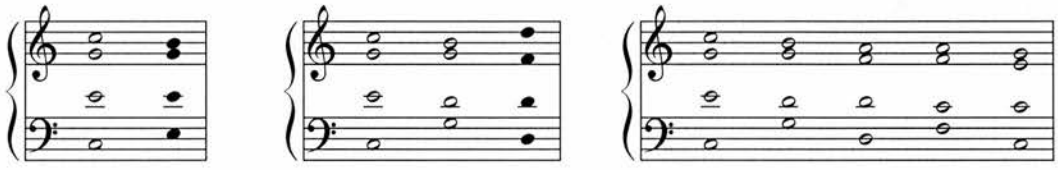
(a) Initial sequence (b) Bass choices (c) Final sequence

Figure 8.5: Exercise 13.2, evaluator A

Exercise 13.3 (sequence I – V – ii – IV – I)

Evaluator A constructed a correct first chord and an incorrect second chord as shown in Figure 8.6(a). After correcting the second chord, the evaluator constructed an unacceptable – for beginners — third chord (the fifth is missing) as in Figure 8.6(b). The chord was corrected and the sequence was finished as in Figure 8.6(c).

[7]At this stage of learning repeated pitches in different voices are not allowed.

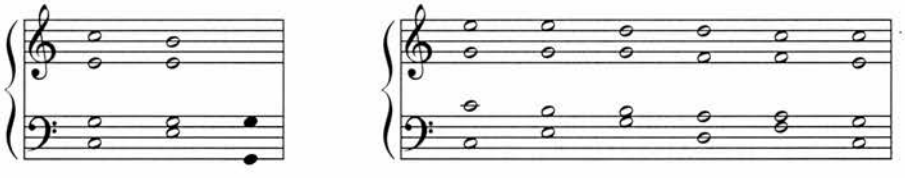


(a) Incorrect chord (b) Incorrect chord (c) Final sequence

Figure 8.6: Exercise 13.3, evaluator A

Exercise 13.4 (sequence I – iii – V – ii – IV – I)

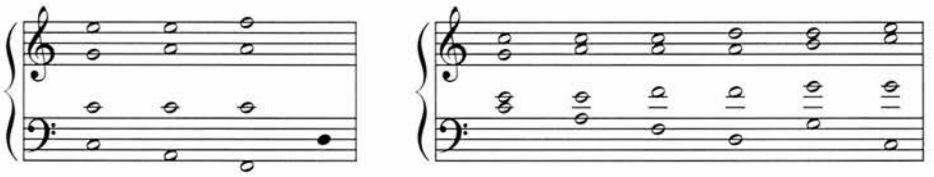
After constructing the first two chords of the sequence as in Figure 8.7(a), evaluator A realised that he would not be able to construct the third chord and still achieve a correct connection. The bass voice cannot be assigned to G_2 (bottom filled note) because the leap of a sixth is not allowed, or to G_3 (top filled note) because this note should be kept sounding at the tenor. The solution devised by the evaluator was to provide more room between the bass and tenor voices as shown in Figure 8.7(b), but this required him to return to the very first chord of the sequence and rebuild it.



(a) Initial sequence (b) Final sequence

Figure 8.7: Exercise 13.4, evaluator A

Exercise 13.5 (sequence I – vi – IV – ii – V – I) Evaluator's A initial choice for the first chord of the sequence made him unable to construct the fourth chord of the sequence, because the environment would not accept a sixth leap interval on the bass voice, as shown in Figure 8.8(a). He had to reconstruct the first chord of the sequence with the bass an octave higher in order to accommodate the descending bass line from C_4 to D_3 presented in Figure 8.8(b), the only one that would allow the completion of the exercise.

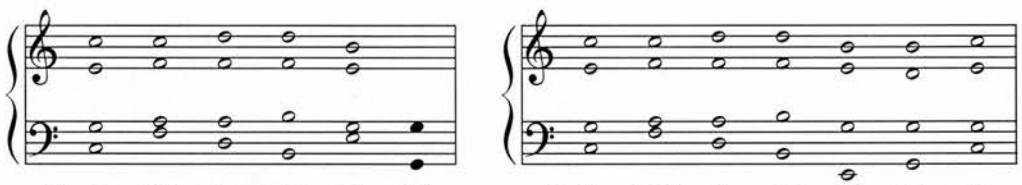


(a) Initial sequence (b) Final sequence

Figure 8.8: Exercise 13.5, evaluator A

Exercise 14.1 (sequence I – IV – ii – vii^o – iii – V – I)

Figure 8.9(a) shows the first five chords constructed by the evaluator for this sequence. Similarly to Figure 8.7(a), the bass voice cannot be assigned, for chord V, to G_2 (bottom filled note) because the leap of a sixth is not allowed, or to G_3 (top filled note). In this particular case, just changing the bass note for chord iii was enough to enable the evaluator to complete the sequence as in Figure 8.7(b).



(a) Initial sequence (a) Initial sequence

Figure 8.9: Exercise 14.1, evaluator A

Exercise 14.2 (sequence I – V – ii – vii^o – iii – V – I)

The evaluator constructed the sequence given in Figure 8.10 very confidently, without receiving any error message regarding incorrect chord construction or chord connection from the environment.

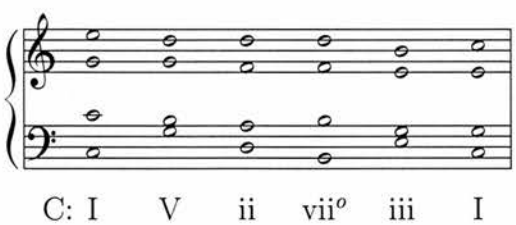


Figure 8.10: Exercise 14.2, evaluator A

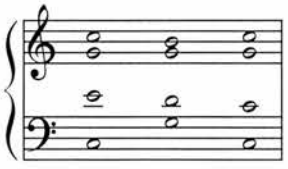
8.3.2 Evaluator B

Personal Background

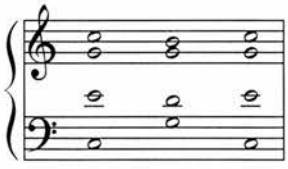
Evaluator B has been teaching harmony for many years to first year and second year students. As evaluator A, he has not centred his teaching on any textbook, and has been developing his own teaching material made up of handouts and a series of exercises. He thinks that the harmonisation of melodies is important (3 or 4/7) for the global assessment of first year harmony students, and that the harmonic analysis of musical pieces from the eighteenth and nineteenth centuries is also important (4/7). As evaluator A, he also believes that it could be feasible to run an undergraduate course centred on Schoenberg (1990), but it would take longer than he is used to to teach. Because of that, he is not sure about how such a course would be accommodated within the context of the other courses. His opinion is that Schoenberg's ideas could be used in an introductory harmony course centred on chord progression, intended for new students not having some harmony background (currently a minority). After interacting with the environment, he showed interest about the possibility of using it, if a couple of more features were to be added, in this introductory course that is being discussed and planned within the Faculty of Music.

Exercise 12.1 (I – V – I)

In this introductory exercise to the discovery mode, after the observer described the focus mechanism as for evaluator A (see page 157), evaluator B constructed the sequence shown in Figure 8.11(a). The last chord of the sequence is not correct (the root degree appears three times), and evaluator B corrected it as in Figure 8.11(b).



(a) Initial sequence

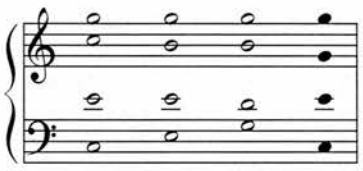


(b) Final sequence

Figure 8.11: Exercise 12.1, evaluator B

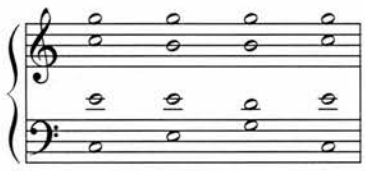
Exercise 13.1 (sequence I – iii – V – I)

As shown in Figure 8.12(a), evaluator B constructed correctly the first three chords of the sequence. However, the next chord was not according to the construction (the doubling tone chosen was the fifth) and connection instructions (the movement of the individual voices could be smaller), and it was refused by the system. Figure 8.12(b) shows the correct chord inserted by the evaluator just after.



C: I iii V I

(a) Initial sequence



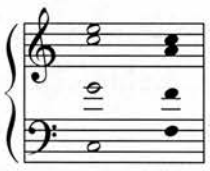
C: I iii V I

(b) Final sequence

Figure 8.12: Exercise 13.1, evaluator B

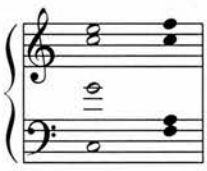
Exercise 13.2 (sequence I – IV – vi – I)

The choice for the first chord of the sequence, shown in Figures 8.13(a) and (b), made the evaluator unable to construct a correct second chord with a proper connection. The reason is that the tenor voice must go up a step, which is outside



C: I IV

(a) Wrong connection

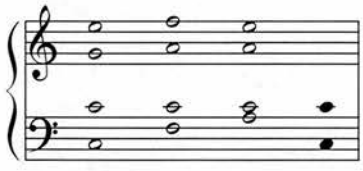


C: I IV

(b) Another wrong connection

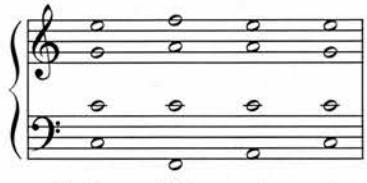
C: I

(c) New first chord



C: I IV vi I

(d) Bass choices (fourth chord)



C: I IV vi I

(e) Final sequence

Figure 8.13: Exercise 13.2, evaluator B

the tenor voice range. Evaluator B tried to construct two different second chords: the one shown in Figure 8.13(a) is correct, but the connection with the first chord is not; the one shown in Figure 8.13(b) is not correct (there is a leap of a seventh in the tenor voice). The evaluator returned to the first chord to rebuild it, but his first attempt resulted in the incorrect chord (the third is doubled instead of the root) shown in Figure 8.13(c) which was refused by the system. The second attempt, shown in Figure 8.13(d), enabled him to reach the last chord but, again, there was no solution for the bass note. The sequence was finally rebuilt as in Figure 8.13(e).

Exercise 13.3 (sequence I – V – ii – IV – I)

This sequence was constructed as in Figure 8.14 without the evaluator receiving from the environment a single error message regarding chord construction or connection.

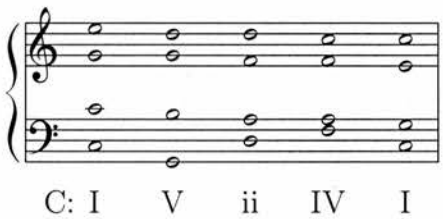


Figure 8.14: Exercise 13.3, evaluator B

Exercise 13.4 (sequence I – iii – V – ii – IV – I)

Again, the sequence was constructed as in Figure 8.15 without difficulty.

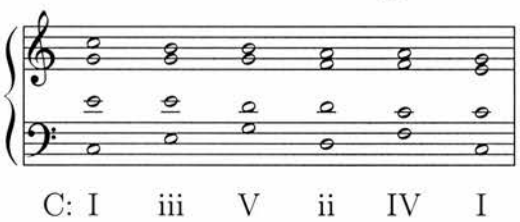
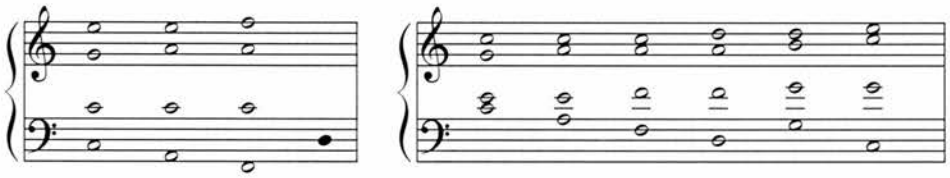


Figure 8.15: Exercise 13.4, evaluator B

Exercise 13.5 (sequence I – vi – IV – ii – V – I)

The sequences constructed by evaluator B, shown in Figures 8.16(a) and (b), were exactly the same as the ones constructed by evaluator A. The same comments on page 159, referring to Figure 8.8, apply to the sequences constructed by evaluator B.



(a) Initial sequence (b) Final sequence

Figure 8.16: Exercise 13.5, evaluator B

Exercise 14.1 (sequence I – IV – ii – vii^o – iii – V – I)

This sequence containing a chord on the seventh degree, which requires the preparation and resolution of the dissonance (the diminished fifth), was constructed as in Figure 8.17 by evaluator B without difficulty.

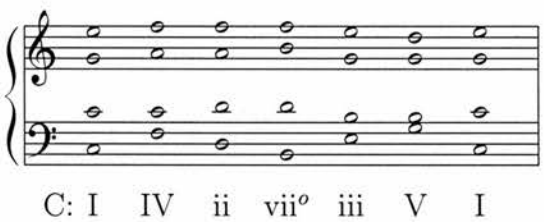


Figure 8.17: Exercise 14.1, evaluator B

Exercise 14.2 (sequence I – V – ii – vii^o – iii – V – I)

As the previous sequence, this sequence demanded the preparation and resolution of chord on the seventh degree, and it was constructed as in Figure 8.18 by evaluator B without difficulty.

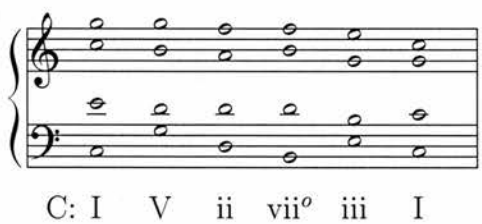


Figure 8.18: Exercise 14.2, evaluator B

8.3.3 Evaluator C

Personal Background

Evaluator C has been teaching harmony privately and at the University for undergraduate and graduate students. As evaluators A and B, he has not been centring his teaching on any textbook, and has been using the same teaching material as them. He thinks that the harmonisation of melodies is important (4 or 5/7) for the global assessment of first year harmony students, and that the harmonic analysis of musical pieces from the eighteenth and nineteenth centuries is very important (6 or 7/7).

When asked if it could be feasible to run an undergraduate course centred on Schoenberg (1990), he said he could not see any reason why not, as this book is "just one the main books on the subject". However, in contrast to the other two evaluators, he did not expand further his thoughts on that.

Exercise 12.1 (I – V – I)

In this introductory exercise to the discovery mode, after the observer described the focus mechanism as for evaluators A and B (see exercise 12.1 on pages 157 and 161), evaluator B constructed the sequence shown in Figure 8.19 without difficulty.

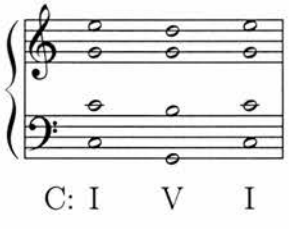
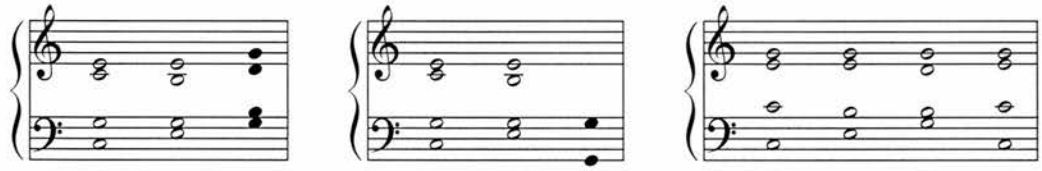


Figure 8.19: Exercise 12.1, evaluator C

Exercise 13.1 (sequence I – iii – V – I)

Figure 8.20(a) shows the first three chord constructed by evaluator C, where the third one was not accepted by the environment because its connection with the second chord was not correct, and the evaluator was unable to move forward. In fact, there was no possible correct connection for this choice of second chord, as no possible note can be allocated to the bass for the third chord, as depicted

in Figure 8.20(b). The bass voice cannot be assigned either to G_2 (bottom filled note) because the leap of a sixth is not allowed, or to G_3 (top filled note) because this note should be kept sounding at the tenor voice. Evaluator C then returned to the first chord, reconstructed it in such a way to provide more room between the bass and tenor voices, and completed the sequence as shown in Figure 8.20(c).

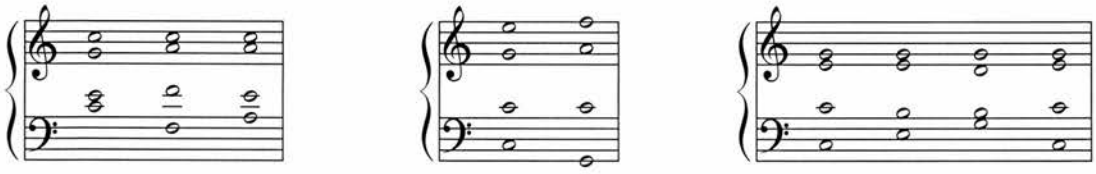


(a) Wrong connection (b) Bass choices (c) Final sequence

Figure 8.20: Exercise 13.1, evaluator C

Exercise 13.2 (sequence I – IV – vi – I)

Evaluator C constructed the sequence as in Figure 8.21(a), which is correct. However, a bug resulting from an incorrect coding of this particular connection for the environment (the top note was incorrectly coded as a D_5 instead of C_5) made the evaluator unable to move forward. The observer perceived from the feedback message the source of the error, explained to the evaluator about the likely causes of that error, and suggested that the evaluator to return to the first chord and alter its notes. The evaluator changed the first chord to an open position chord and constructed a valid second chord having the correct connection with the first one. However, another incorrect coding for this particular connection (the whole second chord coding was incorrect) again made the evaluator unable to move



(a) Correct connections (b) Correct connection (c) Alternative sequence

Figure 8.21: Exercise 13.2, evaluator C

forward. The observer decided to change the sequence manually, in order to not invalidate the study, to the one shown in Figure 8.21(c), which was then correctly completed by the evaluator.

Exercise 13.3 (sequence I – V – ii – IV – I)

Evaluator C constructed this sequence as in Figure 8.22 without receiving error messages from the environment.

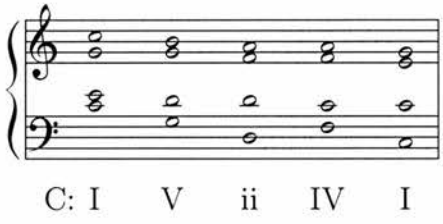


Figure 8.22: Exercise 13.3, evaluator C

Exercise 13.4 (sequence I – iii – V – ii – IV – I)

Again, the sequence was constructed by the evaluator as in Figure 8.23 without difficulty.

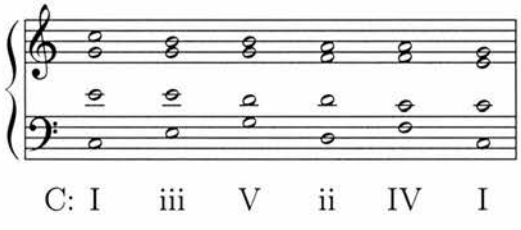


Figure 8.23: Exercise 13.4, evaluator C

Exercise 13.5 (sequence I – vi – IV – ii – V – I)

Evaluator C started constructing the open chord having the soprano note as the highest possible pitch for its voice, and tried to connect it to the chord shown in Figure 8.24(a). As the chord was incorrectly formed (the fifth was doubled instead of the root), it was refused by the system. The user changed the second chord to the one in Figure 8.24(b), which was well formed but the connection was incorrect. In fact, there were no correct connection for the initial choice for the first chord, because the soprano should move up a step to the nearest chord tone as shown in Figure 8.24(c), but this note (A_5) was outside the soprano voice range.

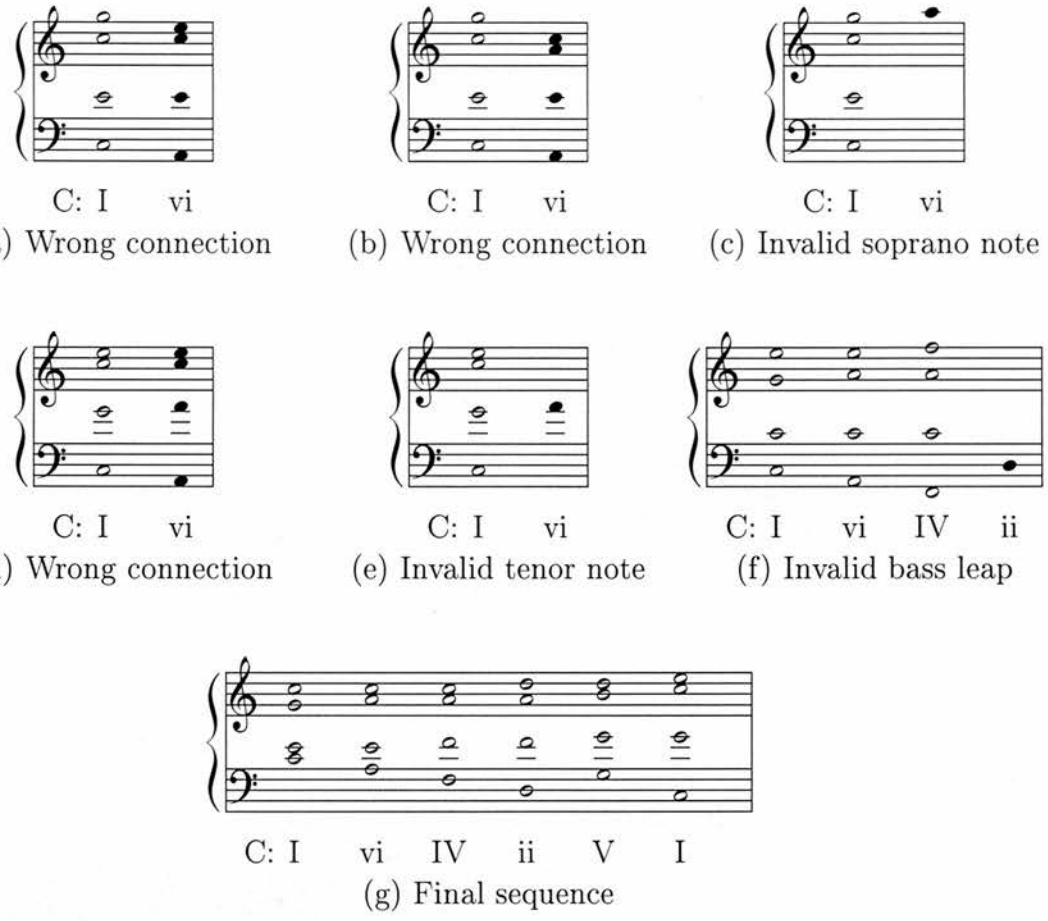


Figure 8.24: Exercise 13.5, evaluator C

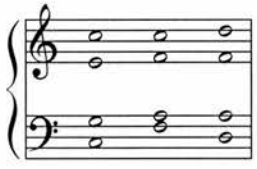
The evaluator then rebuilt the first chord and tried to connect it as in Figure 8.24(d) but again the connection was refused by the system. This was because the tenor note should move up a step to the nearest chord tone as shown in Figure 8.24(e), but this note (A_4) was outside the tenor voice range.

The evaluator then rebuilt the first chord and was able to construct the first three chords of the sequence as in Figure 8.24(f), but he realised that there was no correct connection for the fourth chord. This was because there was only one possibility for the bass note, which corresponds to a forbidden sixth interval.

Finally, the user returned to the first chord, and changed it to accommodate the descending bass line from C_4 to D_3 presented in Figure 8.24(g), the only one that would allow the completion of the exercise.

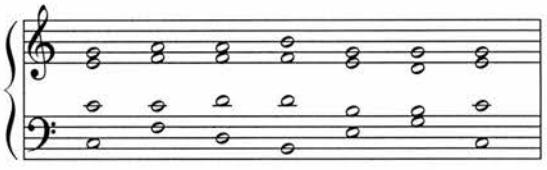
Exercise 14.1 (sequence I – IV – ii – vii^o – iii – V – I)

Evaluator C constructed the sequence as in Figure 8.25(a), which is correct. However, a bug resulting from an incorrect coding of this particular connection for the environment (the top note was incorrectly coded as a C_5 instead of D_5) made the evaluator unable to move forward. The observer recognised again the source of the error from the feedback message, explained the likely causes of that error to the evaluator, and suggested that the evaluator return to the first chord and alter its notes. The sequence then constructed is shown in Figure 8.25(b).



C: I IV ii

(a) Correct connections



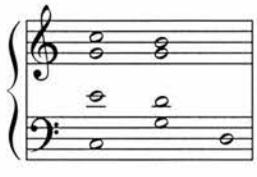
C: I IV ii vii^o iii V I

(b) Final sequence

Figure 8.25: Exercise 14.1, evaluator C

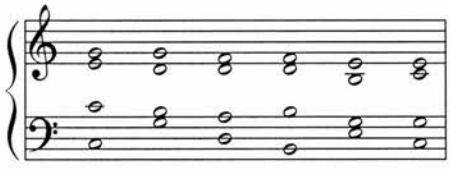
Exercise 14.2 (sequence I – V – ii – vii^o – iii – V – I)

Evaluator C started constructing the sequence in Figure 8.26(a) and, when putting the bass note for the third chord, realised that if he proceeded from this point the ii–vii^o–iii assignment of notes would be the same one as in the previous exercise (see Figure 8.25). Even though there would be no difficulty in completing the exercise, the evaluator decided to return to the first chord and change its notes in order to reproduce the same ii–vii^o–iii as appears in Schoenberg (1990, p.52, Fig. 13(a)), as shown in Figure 8.26(b).



C: I V ii

(a) Initial sequence



C: I V ii vii^o iii I

(b) Final sequence

Figure 8.26: Exercise 14.2, evaluator C

8.4 Analysis of Results

This section provides an analysis of the results, and details the answers to the questions posed in Section 8.1.3. For each one of the questions (which are numbered as in § 8.1.3) a summary of the answers is also provided.

1. **Is the user selecting firstly the bass note for each chord?**
   The observation of the interaction and the analysis of the dribble files showed that the three evaluators were consistently selecting firstly the bass note for each chord.

Evaluator A	Evaluator B	Evaluator C
Yes	Yes	Yes

2. **Is the second note selected by the user, for the first chord in a sequence, the soprano note?**
   The observation of the interactions and the analysis of the dribble files showed that only evaluator B was selecting the soprano as the second note when building the first chord of a sequence, as summarised below.

Evaluator A	Evaluator B	Evaluator C
No	Yes	No

3. **Is the second note selected by the user, for the second and later chords, a common note to the current and previous chord or the resolution of the dissonance (if present)?**
   The observation of the interaction and the analysis of the dribble files showed that only evaluator B was selecting the common note or resolving the dissonance (where appropriate) as the second note for the second and later chords.

Evaluator A	Evaluator B	Evaluator C
No	Yes	No

4. **Is the music notation interface appropriate for the method?**
   As in the formative evaluation study described in Chapter 6, the observation of the interactions and the analysis of the dribble files showed that all

evaluators were able to quickly acquire familiarity with the use of the mouse buttons to insert notes on, and delete notes from, the musical canvas. The evaluators answered positively to this question, which was posed after the interaction session.

Evaluator A	Evaluator B	Evaluator C
Yes	Yes	Yes

The following related question was also posed after each interaction session: *(a) On a scale of 1 to 7, where 1 is very difficult and 7 is very easy, how easy did you find using the mouse to insert and delete notes?*
Evaluators A and B did not find very easy to use the mouse during the first interaction session, which became in fact a pilot session as described in Section 8.2.4, and they answered 3 and 4 respectively to this question. After the second interaction session (performed only by evaluator A and B in a notebook with a 14.1 inches screen[8], with a different mouse) they raised the score to 5. They said this was because of the use of a different computer with a different mouse. Evaluator A thought that the difficulty he felt was not caused by the environment itself, and was because of himself. Evaluator C found it reasonably easy to use the mouse to insert and delete notes, and his answer in both interaction sessions was 6.

Finally, a complementary question was also posed after each interaction: *(b) Might the answer (to question (a) above) be different for users in the target group (beginners)?*
Except for evaluator C, who thought that the answer would be the same for users in the target group, evaluators A and B believed that the target group would have less difficulty in using the mouse because of their familiarity with the use of a computer. The answers to questions (a) and (b) above are summarised below.

[8]All other evaluation sessions were performed on a Sun workstation, with the prototype window almost filling the whole 21 inches monitor

Question	Evaluator A	Evaluator B	Evaluator C
(a)	5	5	6
(b)	>5	>5	6

5. **Is the use of the <Next> button, to move to the next chord in a sequence after finishing the construction of the current one, an intuitive way of representing Schoenberg's left-to-right pedagogical constraint?**

   The observation of the interactions, the analysis of the dribble files and the evaluator's semi-structured interview responses showed that all evaluators found that the <Next> button was representing Schoenberg's left-to-right pedagogical constraint in an intuitive way.

Evaluator A	Evaluator B	Evaluator C
Yes	Yes	Yes

6. **Is the sequencing of topics consistent with the method?**

   The evaluators were unanimous in finding the environment's sequencing of exercises consistent with Schoenberg's method, as shown by their answers to the question below, posed after each interaction session.

   On a scale of 1 to 7, where 1 is not consistent at all and 7 is very consistent, how consistent was the environment's sequencing of exercises to the one in Schoenberg's method?

Evaluator A	Evaluator B	Evaluator C
7	7	7

7. **Is the control of behaviour of the user appropriate?**

   Evaluator B said that, in his opinion, the control of the student's behaviour was appropriate. However, he said that his answer was based on the reservations he had about the method, but that within Schoenberg's parameters was quite appropriate (therefore the number having the symbol * in the table below should be 7). Evaluators A and C said that the control of the student's behaviour was very appropriate. The question posed after each

interaction session asked the evaluators to give a degree of appropriateness: *On a scale of 1 to 7, where 1 is not appropriate at all and 7 is very appropriate, how appropriate was the control of the student's behaviour?*

Evaluator A	Evaluator B	Evaluator C
7	5*	7

8. **Is the didactic feedback given at the end of exercises, and also after chord constructions, helpful for the user in correcting the mistake(s)?**

   The observation of the interactions showed that the evaluators were capable of correcting mistakes after receiving didactic feedback referring to an incorrect chord or chord connection. All evaluators found the feedback significantly meaningful and helpful for correcting later exercises in the same topic, and they think that users in the target group would find the same, as shown by their answers to the questions below, posed after each interaction session.

   (a) On a scale of 1 to 7, where 1 is not meaningful at all and 7 is very meaningful, how meaningful was the feedback given at the end of exercises?
   (b) Might the answer be different for users in the target group?
   (c) On a scale of 1 to 7, where 1 is not helpful at all and 7 is very helpful, how helpful was the feedback provided for correcting later exercises in the same topic?
   (d) Might the answer be different for users in the target group?

Question	Evaluator A	Evaluator B	Evaluator C
(a)	6	6	6
(b)	6	6	6
(c)	6	6	6
(d)	6	6	6

9. **Is Schoenberg's exploration of solutions properly embodied in the prototype?**

   All evaluators answered positively to this question.

Evaluator A	Evaluator B	Evaluator C
Yes	Yes	Yes

10. **Was the design decision of taking away from students the responsibility of choosing the chord sequence to work with beneficial to learning?**

    Except for evaluator C, who found the medium beneficial, the evaluators found it was very beneficial to learning the design decision of taking away from students the responsibility of choosing the chord sequence to work with. However, evaluators A and B emphasised that it is only beneficial to start with, and later on more freedom of choice must be given to students. The following question was posed to evaluators after the interaction with the environment.

    On a scale of 1 to 7, where 1 is not beneficial at all and 7 is very beneficial, how beneficial was to learning the design decision of taking away from students the responsibility of choosing the chord sequence to work with?

Evaluator A	Evaluator B	Evaluator C
7	5*	7

11. **Is it better to leave students responsible for assessing their exercises by themselves, as suggested in Schoenberg's method, rather then receiving didactic feedback after each chord construction?**

    Evaluators A and C thought it would be better for students to receive the didactic feedback after each chord construction. Evaluator B, on the other hand, believed that the students could rely only on the feedback from the environment – as he did himself during the interaction – and not think about what is correct or incorrect in their own solutions. Because of that, he suggested the introduction of a sort of timer to delay the didactic feedback to let some time for the students to think about what they did.

Evaluator A	Evaluator B	Evaluator C
No	Yes	No

12. **Is it better to leave students responsible for getting aural feedback**

(from a musical instrument) rather than having it readily available as in the prototype?

Evaluators B and C believed that it is better to have the aural feedback given by the prototype, while evaluator A believed that, if a musical instrument is available it would be better to leave students responsible for getting aural feedback from it.

Evaluator A	Evaluator B	Evaluator C
Yes	No	No

8.5 Summary of the Results

The evaluation study described in this chapter confirmed most of the claims that had been made during the development of this research. The expert evaluators who assessed the learning environment were able to understand and operate it very quickly. The background information collection (see Appendix B, pages 273, 281 and 281) confirmed the original hypotheses, described in Section 1.3, of the importance of harmonic analysis and harmonisation of melodies to traditional methods of teaching harmony: for the former the ratings were 7/7, 3/7 to 4/7 and 4/7 to 5/7 (evaluators A, B and C respectively), while for the latter their ratings were 7/7, 4/7 and 6/7 to 7/7. Evaluator B, who is more involved with the teaching of harmony for first year students, thought it would be convenient to use an expanded version of the environment with beginner students who lack the knowledge of chord progressions, in order to take account of the assumed background knowledge for the first year harmony course.

Specifically the answer to questions 2 and 3 in Section 8.1.3 show that only evaluator B was following Schoenberg's suggested construction and connection steps. Evaluators A and C were filling notes from the bottom (the bass) to the top (the soprano) voice. We believe that this was because they were not quite able to change their way of solving harmonic problems.

On question 11 evaluator B, in contrast to evaluators A and C, suggested that it would be better for a student not to receive so much feedback from the environment. He suggested that it would be useful to incorporate in future versions

of the environment a delay in the presentation of feedback to the students, in order to leave them some time to think about their solutions.

Evaluator A, in contrast to the other evaluators, indicated that he believed that it would be better for students to get aural feedback from a musical instrument rather than from the environment. However, he said it was fine to receive such feedback from the environment when a musical instrument is not available. We believe that this answer is related to the fact that evaluator A is a very active and experienced performer.

On all the other questions there was a strong agreement between evaluators: as it can be seen in the analysis of questions 3 to 10 presented in the previous section, all evaluators agreed that the prototype was faithfully representing Schoenberg's method of teaching harmony.

Chapter 9

Discussion and Conclusion

This chapter discusses the main research questions posed in Section 1.5 and presents their possible answers. Open areas for further work are identified and a conclusion is presented.

9.1 Revisiting the Questions

The main question we are addressing in this dissertation is posed in Section 1.5, and reproduced here for the reader's convenience:

> *Is it possible to design and construct a computer-based learning environment presenting the pedagogy and curriculum of Schoenberg's method while remaining true to its spirit?*

This question was decomposed in Section 8.1.3 into the set of more manageable questions below. The next section details the answers to these questions.

1. Is it possible to formalise the rules of Schoenberg's harmonic method in such a way that they are amenable for use in a computer-based environment?

2. Is it possible to embody the basic principles of chord construction and connection as specified in Schoenberg's method in such an environment?

3. Can the materials of Schoenberg's method be delivered by a computer-based learning environment so as to explore the full range of activities available in a way appropriate to the method?

4. Is there a satisfactory means by which we can make such formalised materials (see '3' above) potentially accessible to the user?

9.2 Answering the Questions

This section details how each of the questions presented above is being addressed in this dissertation, and links to the relevant parts are provided.

1. *Is it possible to formalise the rules of Schoenberg's harmonic method in such a way that they are amenable for use in a computer-based environment?*
   Chapter 4 provides a formalisation of part Schoenberg's method for teaching harmony, which was incorporated in the prototype learning environment described in Chapter 7. Schoenberg's "chief aim (in this book) was to present the craft of harmony (...) as systematically as possible, leading the pupil step by step toward mastery of that craft" (Schoenberg, 1990, p. xiv, Roy E. Carter's preface). This presentation involves the adaption of the rules, as students evolve throughout the curriculum, to the new context. As Schoenberg is concerned in being systematic in his method, and new rules are built on top of the formalised rules in Chapter 4, which form the core of the method, the complete formalisation of the method would be straightforward. This, in conjunction with the existence of the prototype learning environment, and the evaluation study described in Chapter 8, particularly in its question 5 to 7 in Section 8.4, demonstrates that the answer to question 1 is affirmative: the method can indeed be formalised so as to be amenable for use in a computer-based environment.

2. *Is it possible to embody the basic principles of chord construction and connection as specified in Schoenberg's method in such an environment?*

   The basic principles of chord construction of Schoenberg's method were incorporated into an early human-computer interface (see Chapter 5). The learning environment built on top of it included Schoenberg's chord connection principles, and the evaluation studies of the earlier interface (see

Chapter 6) and of the learning environment (see Chapter 8) demonstrate that the students must comply with Schoenberg's principles of chord construction and connection. For discovery mode exercises, two of the three evaluators did not insert notes according to the voice order assignment suggested by Schoenberg, as shown by the answers to questions 2 and 3 in Section 8.4. We believe that this was because the evaluators were solving the exercises through their own individual ways of solving musical problems in general, and were simply not paying attention to the steps required by the method. From these evaluators, only one (evaluator C in Section 8.2.1) asked why some exercises allowed students to insert notes without following the voice order assignment suggested by Schoenberg's method (see Appendix B, page 301). Beginners probably would tend to follow the voice order assignment enforced by previous exercises. Therefore, the prototypes described in Chapters 7 and 5 and the studies centred on them, as described in Chapter 8 and 6, demonstrate that it is possible to embody the basic principles of chord construction and connection as specified in Schoenberg's method in a computer-based environment.

3. *Can the materials of Schoenberg's method be delivered by a computer-based learning environment so as to explore the full range of activities available in a way appropriate to the method?*

   The learning environment described in Chapter 7 was designed to present students with chord construction and connection exercises consistent with Schoenberg's method. The positive answers from all three evaluators to questions 4 and 5 in Section 8.1.3, and the results of the evaluation study in Chapter 6 demonstrate that these materials were made available through the prototype learning environment described in Chapter 7, which was capable of providing means for the exploration of the full range of activities required by the method.

4. *Is there a satisfactory means by which we can make such formalised materials (see '3' above) potentially accessible to the user?*

The prototype was evaluated by certification, rather than by direct testing with the target user group. However, the very positive answers from the expert evaluators to questions 6 to 9 presented in Section 8.4 indicates that these materials would be potentially accessible by users in the target group.

9.3 Criticism of the Methodology

Possible criticisms of the methodology adopted in the dissertation are being addressed as follows:

- *Could the answers in the interview all just be what they thought we wanted them to say, because they were helpful people?*

  This is a possibility that should not be disregarded. However, as can be seen in the transcription of the semi-structured interview in Appendix B (see pages 273, 281 and 293) the answers given by the evaluators – particularly evaluators B and C – to some questions were not immediate. We believe this is an indication of the fact they were trying to provide accurate answers, according to their individual viewpoints, after thinking carefully about the questions posed. Evaluators who were simply trying to be helpful would be more likely to answer without hesitation.

- *Problems of having to treat as pilot first run through.*

  As mentioned in Section 8.2.4, the first interaction section with evaluators A, B, and C was disregarded and considered to be a pilot study because the environment was faulty: some incorrect connections were being accepted as correct, allowing the evaluators to move to the next chord when they should not. A quick analysis of the dribble files after running of the study showed that the results that could be extracted from them would be meaningful or correct. Because of that, the evaluators were invited for another evaluation session after the source of the incorrect behaviour was identified and fixed.

- *Problems during the second run through.*

  The second run through sessions started with evaluator C, who identified two small bugs still remaining (see Section 8.3.3, Exercise 13.2 on page 166 and Exercise 14.1 on page 169). In these cases, in contrast to the more severe bugs identified during the pilot sessions (in which incorrect connection were being accepted), two particular chord connections were not being accepted. As soon as the observer perceived the bug, he immediately suggested to the evaluator to return back to the first chord and try a different assignment of notes for it. This allowed the constructing of different correct sequences, which were accepted by the environment and prevented the invalidation of the second run through as, in contrast to the bug described in the previous item, the bug was not so severe (and just kept the evaluator stuck on a correct connection). After the session with evaluator C in which the bugs were identified, and before the second session was run with evaluators A and B, the observer made sure that the bug was eliminated from the environment.

9.4 Future Work

Open areas for future research on the material presented in this dissertation can be identified as follows:

- *evaluation with beginners*

  An evaluation study with users in the target group could be run to effectively address question 4 in Section 9.2. This study would need the expansion of the environment as suggested in the next item. This evaluation study was not done in this research because:

  - there was a more urgent need to have of the certification from expert evaluators, as the one conducted in this research, in relation to the main question of how faithful the environment was in relation to the pedagogy and curriculum of Schoenberg's method. An evaluation

study with users in the target group would make sense only after such a certification;

- only a longer term study with an environment embodying a significant part of Schoenberg's method would be able to address additional research questions such as the potential benefits of Schoenberg's method over traditional methods;

- *expanding the environment*

  The expansion of the environment is an obvious next step, and the areas to which this expansion can be made is very wide, as detailed below:

  - *presentation of theoretical background material/feedback*

    Adding to the environment the capability of presenting relevant concepts both in textual mode and through examples in musical notation can eliminate the need of handouts to introduce students to the theoretical background material for each task. Also, this would add to the environment the capability to indicate to the students in a more convenient way the potential source of misconceptions/mistakes they are committing while solving the exercises.

  - *student modelling*

    The introduction of a user model into the architecture of the environment, which would store information about the student's mastery level on the skills, could be used in conjunction with a didactic planner to provide the environment with a dynamic selection of exercises aiming to improve the control of the behaviour of the student.

    Different approaches have been successfully used to build student models, depending on the characteristics of a particular domain (VanLehn, 1988; Greer & McCalla, 1994). Domains in which conceptual learning is the focus a declarative knowledge representation such as the the hierarchy of scripts in WHY (Stevens et al., 1982) or the semantic network in SCHOLAR (Carbonell, 1970) has been traditionally used, differently from domains with emphasis on problem-solving skills, which

use a procedural knowledge representation such as BUGGY's procedural network (Brown & Burton, 1978; Wenger, 1987) or the production rules of the LISP tutor (Reiser et al., 1985). The focus on procedural knowledge of Schoenberg's method suggests that the later approach would be more appropriate to be adopted in an expansion of the learner environment. However, a blend of both approaches would be beneficial, as we would like to students not only to master the rules of harmony but also to articulate justifications for using (or not using) particular rules in given situations. Human-computer interaction issues should also be carefully considered to inform how such a model should be built, used by the didactic planner, and updated.

- *didactic planning*

  The development of an improved version of the didactic coordinator module would allow, when associated with the user model suggested above, a personalisation of the presentation to students, with exercises having a difficulty level tailored to their individual knowledge. The sequencing of exercises can be changed, in such a way as to refer back to previous lessons associated with current weaknesses or to skip lessons when the mastery of the tasks is detected. An architecture based on TAPPER (Wiggins & Trewin, 2000), an aural training system, seems to be a good starting point for such an expansion, as it was devised to allow not only different paths through the curriculum, but also to apply different teaching strategies depending on the performance of the student and on the *teaching concerns* mechanism.

- *lessons*

  A broader range of lessons can be easily added to the current environment, by simply describing new lessons and exercises, jointly with the necessary changes to the domain knowledge, in a form of the associated correct and incorrect (forbidden) chord construction and connection data. Exercises which allow students to formulate chord sequences to work with can be also incorporated, making the environment even

more faithful to Schoenberg's method. It would be the didactic planner's task to decide, based on the current student knowledge, when it would be appropriate to present students with such exercises.

9.5 Conclusions

This work contributed to the teaching of harmony by formalising and providing a framework capable of enabling Schoenberg's method of teaching harmony. This method differs from most other harmony teaching methods in the sense that it presents a consistent and systematic set of principles which are amenable to be modelled in a computer.

The framework was evaluated by two groups of three experts teachers each: the first group evaluated the usability of an early human-computer interface; and a second group assessed how faithful the environment was, when built on top of an improved version of the human-computer interface, representing the pedagogy and curriculum of Schoenberg's method.

Both studies indicate that the proposed framework is a true and good embodiment of Schoenberg's method, and that it seems to be worthwhile to expand further the prototype learning environment for real use in the classroom to evaluate the potential benefits of Schoenberg's method of teaching harmony to the learning of the subject by users in the target group.

Glossary

Arpeggio The employment of the notes of a chord in rapid succession instead of simultaneously. See also Chord. *page 3*

Chord The combination of two or more simultaneous sounding tones, usually represented as a Roman numeral to designate the scale degree on which chords are constructed. *page 3*

Common Practice The denomination given to the harmonic practice of composers of the eighteenth and nineteenth centuries. *page 4*

Counterpoint The art of combining different melodic lines in a musical composition. *page 1*

Form The structure of a musical composition. The term is regularly used in two senses: to denote a standard type, or genre, and to denote the procedures in a specific work. *page 1*

Harmonic Function The way in which chords relate to each other. *page 3*

Harmony The developed system of chords and rules that allow or forbid relations between chords that characterizes Western music. *page 1*

Homophonic A musical texture presenting the same rhytm in all voices, or a single melodic line plus a chordal accompaniment. *page 4*

Key Signature A group of sharp or flat symbols at the beginning of each line of music, which indicates the accidentals necessary to form the diatonic scale on which a musical piece is based. *page 3*

Parallel Fifth A parallel movement between two voices where the initial and final intervals are a fifth and the voices are moving in the same direction. *page 5*

Parallel Octave A parallel movement between two voices where the initial and final intervals are an octave and the voices are moving in the same direction. *page 5*

Rhythm A term used to refer to the disposition of sound in time. *page 1*

Scale Degree Each of the successive notes that form a musical scale. *page 3*

Voice One individual melodic line. *page 2*

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Appendix A

Formative Evaluation Data

This appendix contains the materials used in the evaluation of the usability of the interface (Chapter 6). Transcriptions for the whole study (basic information collection, interaction and semi-structured interview) are also included.[1]

Hand-out 199
Semi-structured Interview Sheet 211
Transcription of the study for evaluator A 215
Transcription of the study for evaluator B 225
Transcription of the study for evaluator C 225

[1]Page numbers for the materials and transcriptions are shown on the right hand side.

EMPIRICAL STUDY ON

A Harmony Teaching Environment Interface

Márcio Brandão*

Description

The goal of this study is to evaluate the usability of a human-computer interface intended to be used in a harmony teaching environment based on Schoenberg's method.

The study consists of four stages. In the first stage some basic background information is requested from you. The second stage involves you acquiring some familiarity with the interface and the tasks, by means of reading background information on section 1 of this handout and using the interface for constructing individual chords. In the third stage you are asked to construct individual chords and sequences of diatonic chords using the mechanisms offered by the interface. Finally, the last stage of this study consists of a semi structured interview that aims to collect from you the overall impression of the interface.

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1 Theoretical Background for all Tasks

1.1 The Diatonic Major Scale

This study deals only with chords based on the *major diatonic scale*. This scale is made up of seven notes that follows one particular distribution of tones and semitones (or whole-tones and half-tones) as shown in Figure 1 for the C-major scale. Figure 2 depicts the same distribution of tones and semitones for the E-major scale (that has a different key signature).

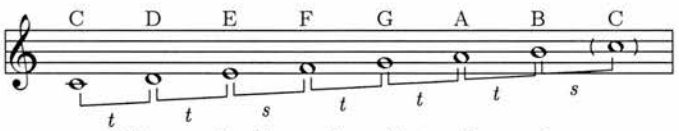

Figure 1: C-major diatonic scale

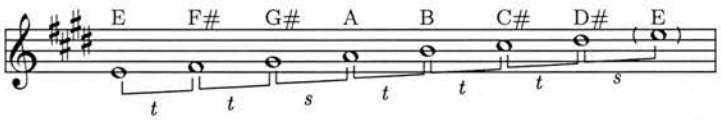

Figure 2: E-major diatonic scale

Roman numerals are used to designate the different scale degrees of the diatonic major scales, as shown in Figure 3 for the C-major scale and in Figure 4 for the E-major scale.

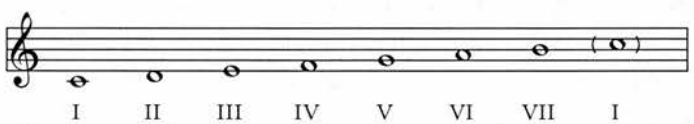

Figure 3: Degrees of the C-major diatonic scale

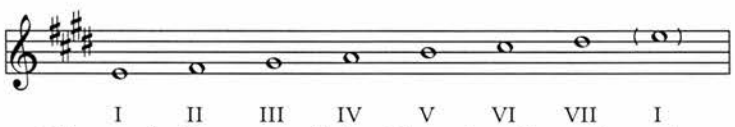

Figure 4: Degrees of the E-major diatonic scale

The chords involved in this study are the basic *triads* constructed using the notes from the above described major diatonic scale. The triads are made up of three notes by means of superposing two thirds consecutively, as shown in Figures 5 and 6 for the C-major and E-major diatonic scales respectively. Note the use of capital and lowercase numerals to indicate the chord type as described below:

- capital Roman numerals to represent a major chord;
- lowercase Roman numerals to represent a minor chords

- lowercase Roman numerals with a superscript ^{o} to represent a diminished chord

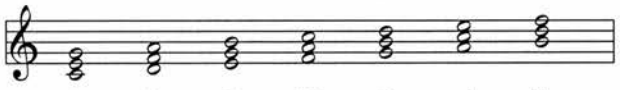

Figure 5: The diatonic triads in C-major

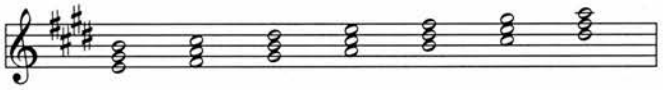

Figure 6: The diatonic triads in E-major

1.2 Four-Part Writing

You will be asked to complete four tasks, as described in section 2.1, 2.2, 3.1 and 3.2. They each involve constructing and connecting chords based on the diatonic triads described in the section 1.1. They correspond to simple exercises involving construction and connection of diatonic triads. Schoenberg suggests that students practice these in the **early stages** of learning harmony. Given this particular context, the task of constructing a chord you will be asked to do requires [1]:

- Four part writing (soprano, tenor, alto and bass voices and ranges are assumed);
- the bass note on the root degree;
- not using the same note twice;
- the following position of chords:

  close when no other chord tone can be inserted between two adjacent voices of the upper three voices; or

  open when one or more chord tones can be inserted between two adjacent voices of the upper three voices. These adjacent voices, however, cannot be separated by more than an octave;

The task of connecting chords must take into account the *law of the shortest way* described below:

- common tones must be kept on the same voice;
- each voice must take the smallest step which will allow the other voices to take small steps.

[1] Schoenberg's method changes constraints as the student acquires individual skills, in such a way that new constraints can be added while others can be relaxed or disregarded at different stages of the curriculum.

The sequence of steps from Schoenberg's method to be carried out in order to achieve a "good" connection of chords having common tones (as in the tasks you will be asked to complete) are listed below. You are requested to use them while interacting with the interface.

1. Bass voice = root degree;
2. keep common tones in the same voices;
3. fill missing tones.

One example of a completed sequence where the above constraints were observed is shown in Figure 7.

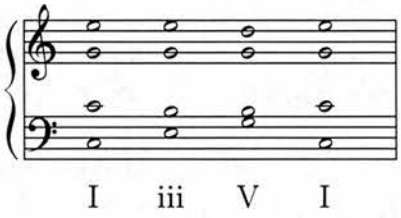

Figure 7: Example of a sequence of chord connections

2 Using the Interface

The interface is shown in Figure 8.

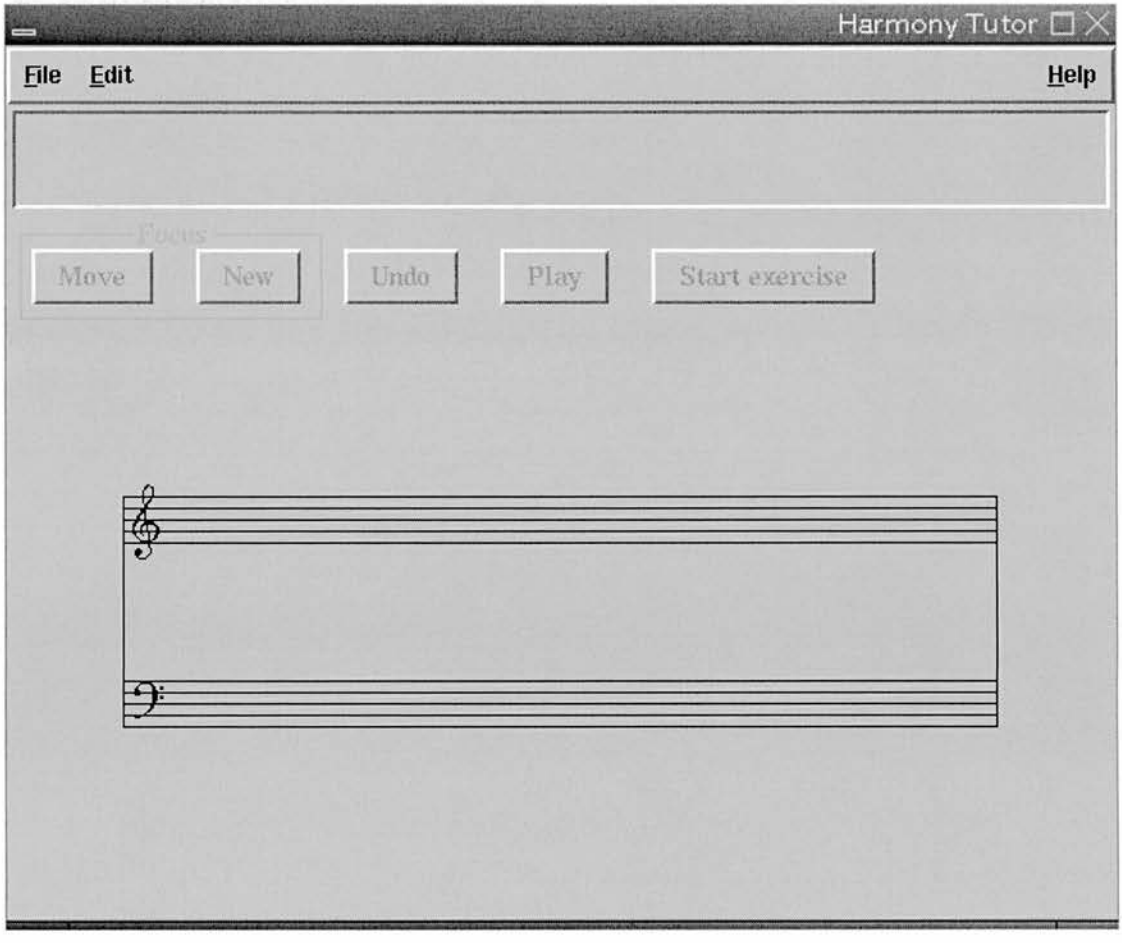

Figure 8: The interface

Click on the File menu, and then click on the New option. Type your name in the New User window as in Figure 9.

Figure 9: New User window

After the greetings from the system, press the "Start Exercise" button to start

the first task, as shown in Figure 10.

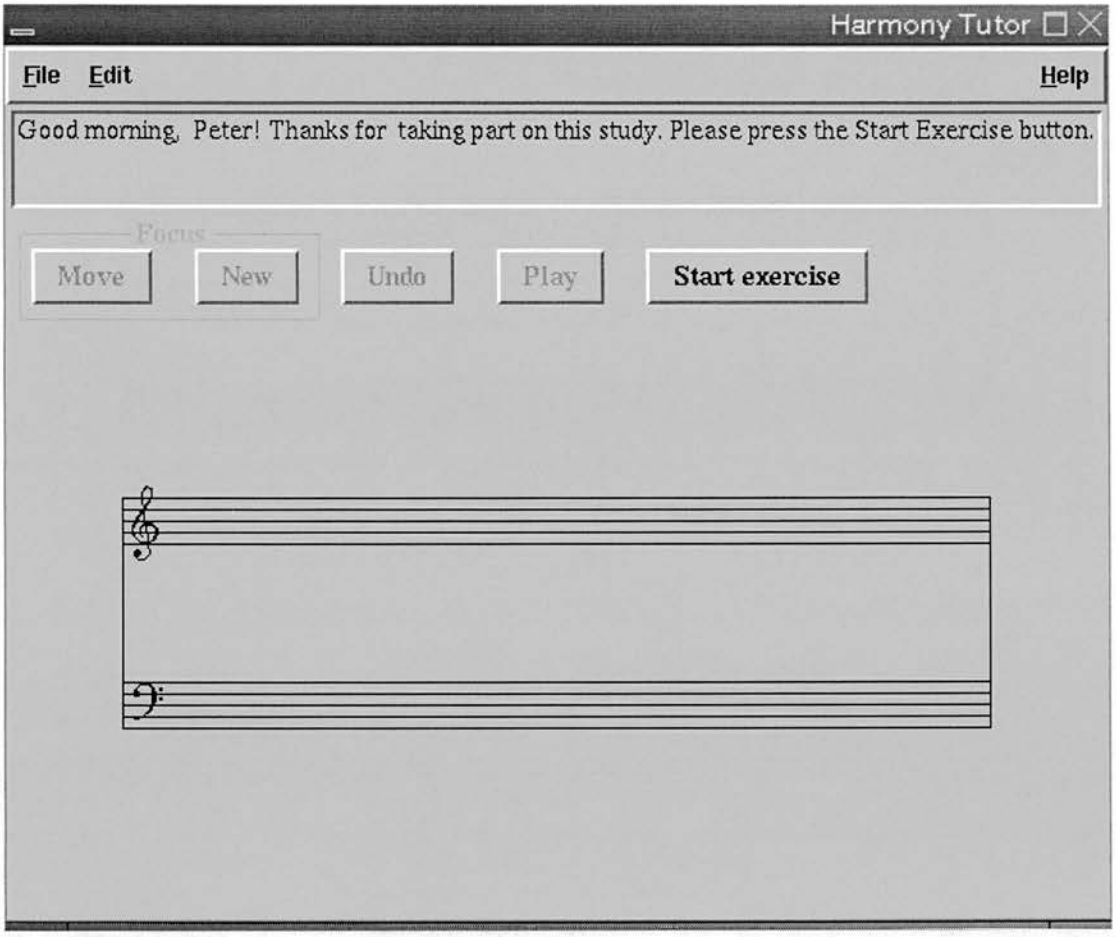

Figure 10: Ready to start...

2.1 Task 1: Construct a chord

You are now asked to construct a four-voice chord on the first degree of the C major scale, as shown in Figure 11.

Using the mouse you can:

- insert notes using the left button within the rectangles; or
- delete notes clicking on previously inserted notes with the right button.

You also can undo the last action by clicking on the "Undo" button. The possible actions (for this task) are:

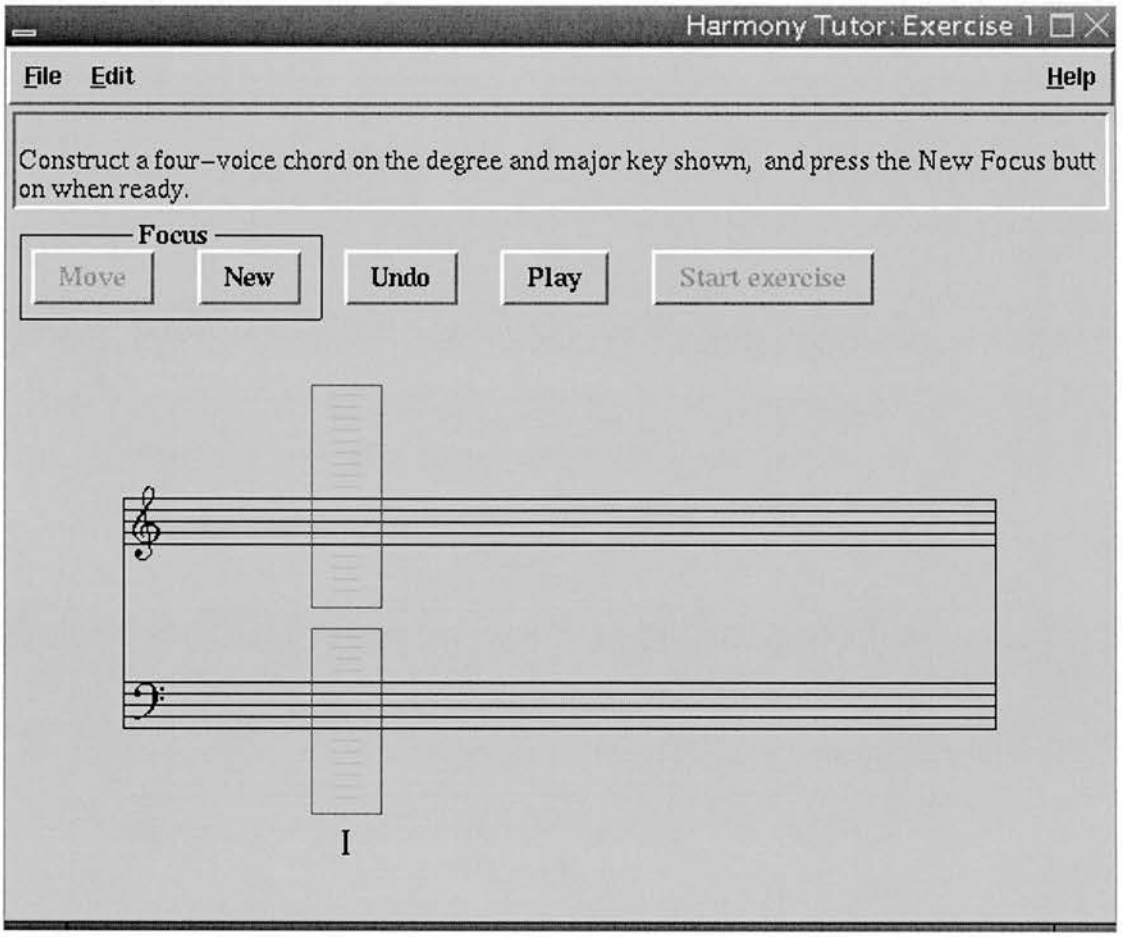

Figure 11: Construction of a C-major chord

- to delete an inserted note;
- to insert back a deleted note.

Try both mechanisms and the "Play" button, through which you can play the chord (or note(s)) you inserted.

When you are happy with your four-voice chord press the "New" (Focus) button.

If there is no error message you can press "Next" to move to the next task. Otherwise you need to correct the chord before being allowed to move.

2.2 Task 2: Construct another chord

You are now asked to construct a four-voice chord on the fifth degree of the G major scale, as shown in Figure 12.

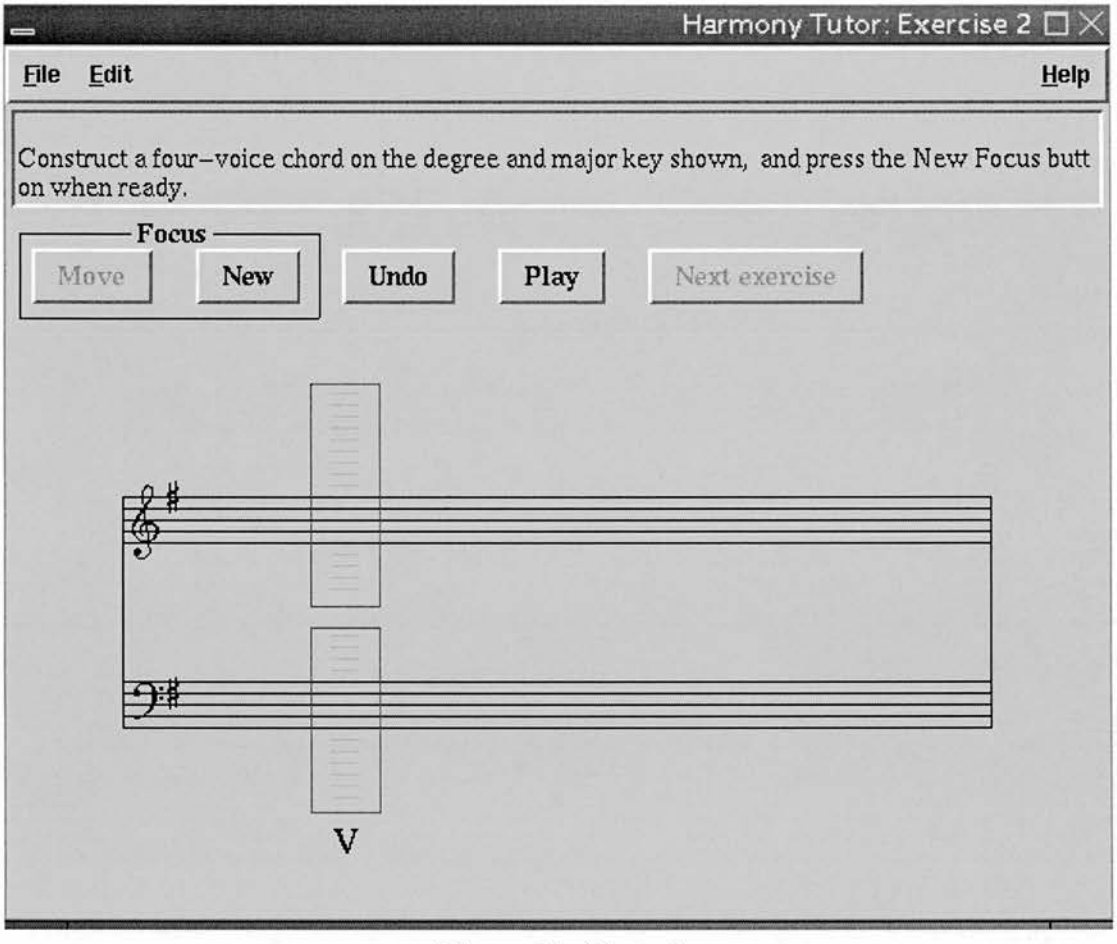

Figure 12: Task 2

Using the same mechanisms described in section 2.1, construct the required D major chord.

3 Tasks Involving Sequences of Chords

3.1 Task 3: Construct a Sequence of Chords

You are now asked to construct the sequence of chords I – V – I on the key of B flat, as shown in Figure 13.

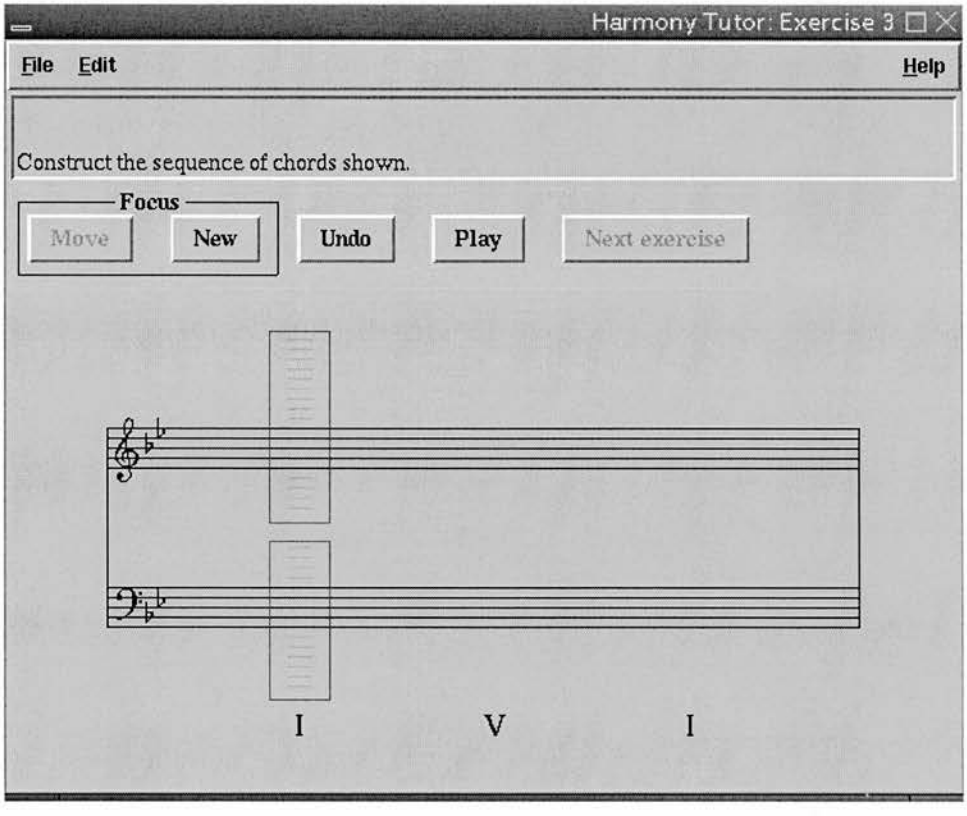

Figure 13: Task 3

After finishing the construction of a chord, click on the "New" button to move the the chord immediately to the right. You will be informed if the chord is not correct, and you will not be able to move to the following one until correct it.

After the construction of more than one chord the "Move" button is enabled, and you can move backwards and forwards in the sequence as shown in Figures 14 and 15. To move the focus you just need to click using the left button of the mouse in any of the highlighted rectangles as in Figure 14. Figure 15 shows what happen if you click on the first chord of the sequence. You can change notes by deleting and inserting notes using the right and left buttons of the mouse, as described in section 2.1.

To return to the righmost worked chord you can:

- use the "New" button to move to the right step by step; or
- use the "Move" button to move straight away to it.

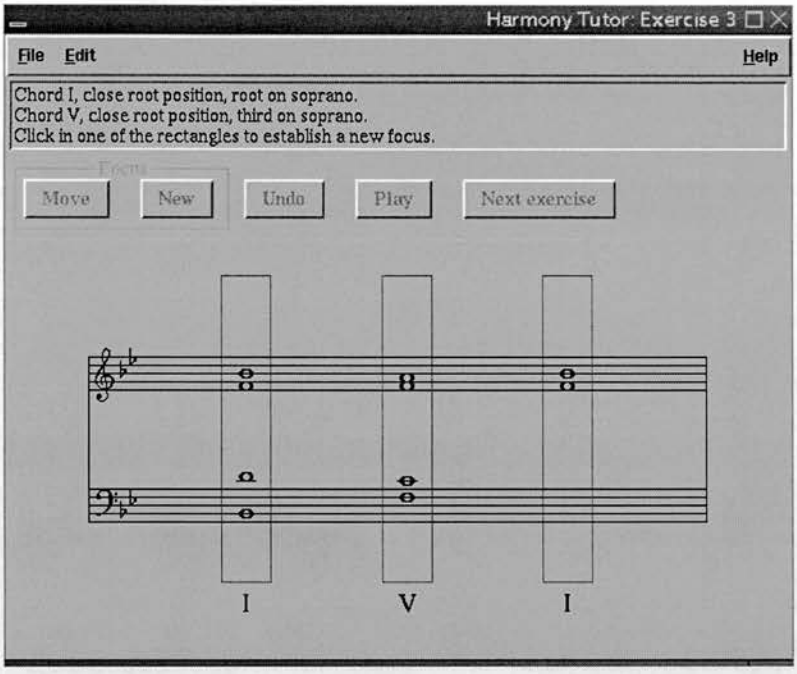

Figure 14: Moving the Focus

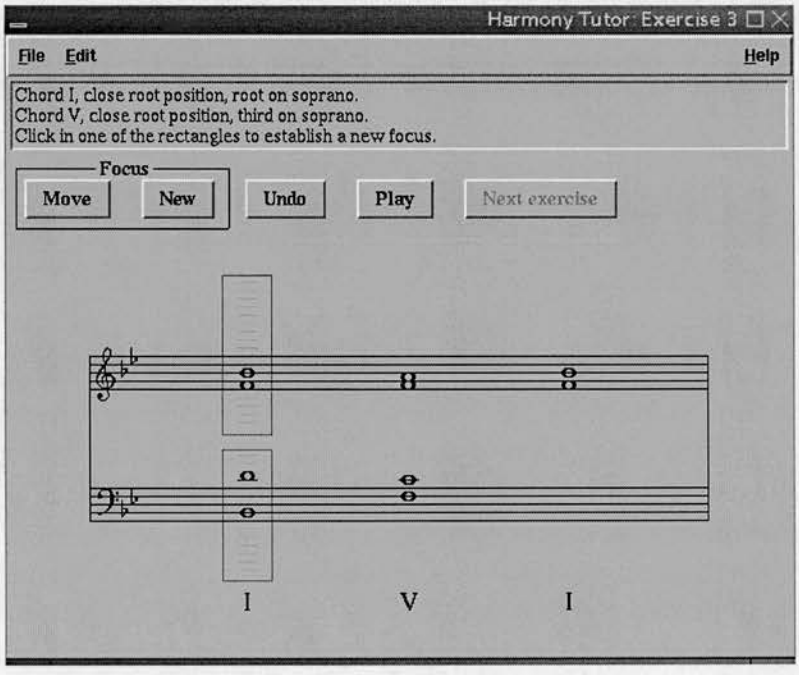

Figure 15: Focus change

3.2 Task 4

Following the same steps and using the mechanisms described in sections 2.1 and 3.1, construct the required I – iii – V – I on the scale of C major as shown in Figure 16.

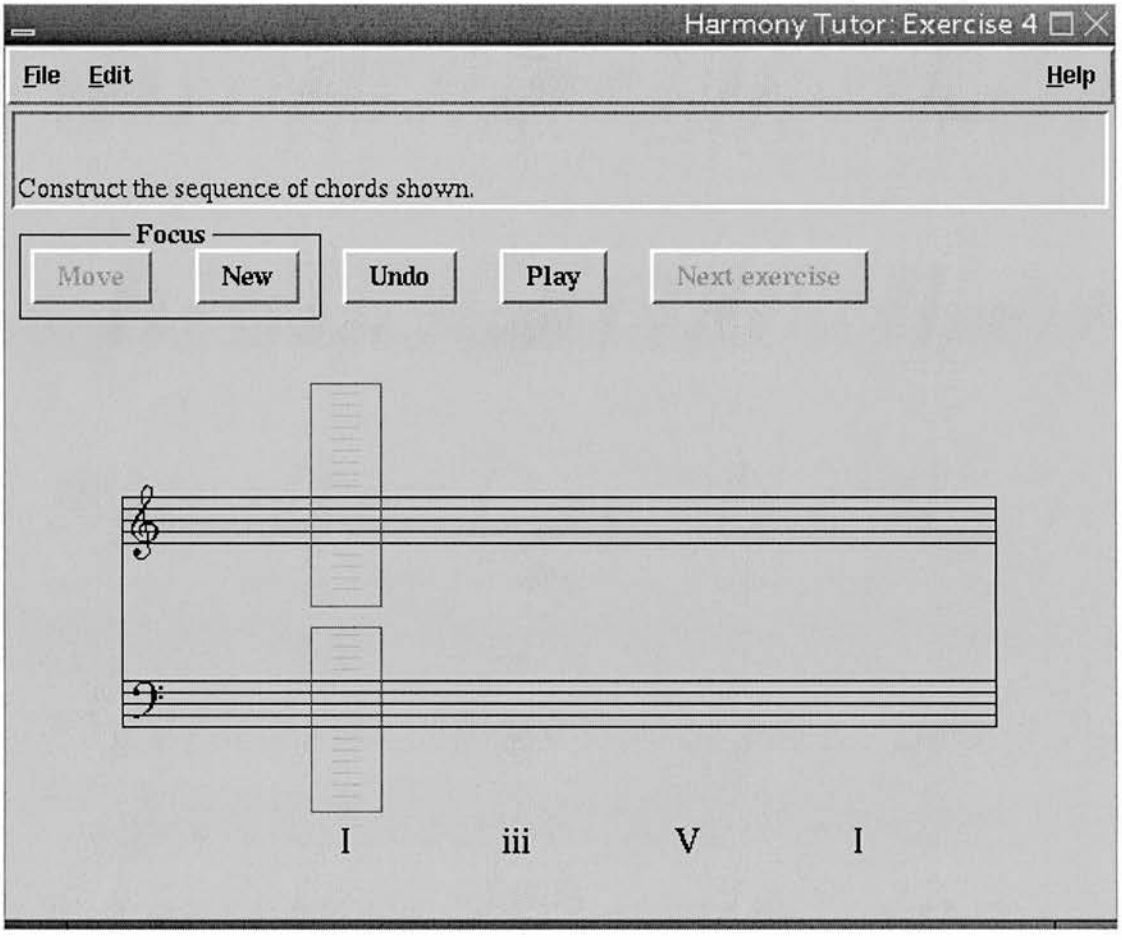

Figure 16: Another sequence of chords

Now a few questions about the interaction are posed to determine your overall impression of the interface.

Thanks for taking part on this study!

Semi-structured Interview Sheet for the Empirical Study on

A Harmony Teaching Environment Interface

Participant: _____

Date: ____ /____ /_____

1 Basic Information

1. Describe your background in music.

2. List the music styles and composers that you are used to listen to.

3. Classify the music styles of your compositions.

4. How do you classify yourself as a computer user?
   Inexperienced [ ] Amateur [ ] Proficient [ ] Expert [ ]

5. How do you classify yourself as a computer user of musical programs such as sequencers and notators?
   Inexperienced [ ] Amateur [ ] Proficient [ ] Expert [ ]

2 Questions (Semi-structured Interview)

1. How easy did you find using the left button of the mouse to insert notes in chords?
   very easy [ ] easy [ ] a little difficult [ ] quite difficult [ ]

   Might the answer be different for users in the target group?

2. How easy did you find using the right button of the mouse to delete notes in chords?
   very easy [ ] easy [ ] a little difficult [ ] quite difficult [ ]

   Might the answer be different for users in the target group?

3. Did you use the "Undo" button to delete an inserted note?
   Yes [ ]. Did you prefer this to using the delete mouse button?

   No [ ]. Did you understand how the "Undo" button works?

   Might the answer be different for users in the target group?

4. Did you use the "Undo" button to insert a deleted note?
   Yes [ ]. Did you prefer this to using the insert mouse button?

   No [ ]. Did you understand how the "Undo" button works?

   Might the answer be different for users in the target group?

5. The "New Focus" button moved the focus to the chord immediately to the right of the current one. How easy did you find this to use?
   very easy [ ] easy [ ] a little difficult [ ] quite difficult [ ]
   Are there alternative ways to move?

   Did you always note the feedback given?

   How useful did you find the feedback?

6. Did you use the "Move Focus" button to move the focus backward in the sequence to chords?

   - Yes [ ]. Having moved backwards, how easy was it to change notes?
     very easy [ ] easy [ ] a little difficult [ ] quite difficult [ ]

How did you move forwards again after changing things?

- No [ ].

7. Did you use the Play button?
   Yes [ ]. Did you find it useful? Why?

   No [ ]. Would you have found it useful?

   Any comments, problems or suggestions for improvements?

8. What would you expect to happen at the end of a task or exercise?

9. Any other comments, problems or suggestions for improvements?

Transcription of Basic Information Collection, Evaluator Interaction and Semi-Structured Interview for the Empirical Study on

A Harmony Teaching Environment Interface

Participant A: Peter Nelson

Date: 29/03/2001

1 Basic Information

1. `Observer:` First of all, I would like to collect some basic information from you.
   Evaluator: OK.
   `Observer:` First of all: Describe your background in music.
   Evaluator: Well, I have an University Degree in Music.
   `Observer:` But you are a Senior Lecturer, is that right?
   Evaluator: Yes.

2. `Observer:` About the music styles. Which music styles and composers do you prefer and are used to listen to?
   Evaluator: Classical styles. You can say classical and romantic.
   `Observer:` What about the electroacoustic (style)?
   Evaluator: Yes. Electroacoustic.

3. `Observer:` And about your compositions. Which areas do you ... ?
   Evaluator: Hm. Electroacoustic and contemporary instrumental.
   `Observer:` It is very difficult to give names, without being unfair. (Laughs)
   Evaluator: (Laughs)
   `Observer:` Sorry. You said contemporary instrumental.
   Evaluator: That's right.

4. `Observer:` About the use of computers, how do you classify yourself as a computer user in this scale?
   Evaluator: Hm (while reading the options). Proficient.

5. `Observer`: Hm, hm. And computer user of musical programs such as sequencers and notators.
   Evaluator: Hm (while reading the options). Expert.

Interaction

`Observer`: OK. That's it from the basic information. That's the last bit. We have a hand-out, perhaps it would be a very good idea for you to take a look. You will find the theoretical background for the tasks. We need to just to highlight that this interface is intended to very beginners in this study of harmony. Just to put some context.
Evaluator: OK.
`Observer`: Probably these basics will be very easy for you to read through.
Evaluator: Maybe (laughs, and start to read the hand-out).
`Observer`: (laughs). I hope you don't mind to video record.
Evaluator: No, absolutely not.
`Observer`: (pointing out informations at the hand-out) These are the Schoenberg's principles, if you like, for being used for the beginners (incomprehensible). (incomprehensible) to reflect this method of construction. And I (would) like if you could please follow these in answering, (that is) solve the tasks using these three principles, first the bass, after the common notes, and (incomprehensible) these common tones.
Evaluator: OK.
`Observer`: So, at this stage, I think you can start interacting with the interface.
Evaluator: All right. (reads the instructions on screen)So, lick on the File menu, and (press) "New". (reads the request to type his name) So, (type his name). OK. (reads the new instruction) Press the "Next" exercise button (press the button at 4m52s of the tape)

Task 1

`Observer`: Before doing the task, I think it's worth reading the page 6[1] of the handout.
Evaluator: Hm, hm (reads the handout). Construct a chord (incomprehensible). Insert notes using the left button (insert the first note at 20s using the left button of the mouse). OK
`Observer`: Yeah.
Evaluator: Delete notes. OK. (delete the note at 26s, and reinsert it at 27s) (press the "Play button at 62s). (incomprehensible, while he reads explanation about the "Undo" button) OK.

[1] See Pages 204 and 205 of this dissertation.

Try both mechanism and the Play button (inserts the remaining notes and press the "Play" button at 49s). That sounds odd.

`Observer`: The sound of the chord, you mean?

Evaluator: Yeah (press the "Play button at 62s, generating a very odd mixture of the major chord shown and a kind of white noise[2])

`Observer`: Interesting. (laughs) Ah, ah.

Evaluator: (laughs) Ah, ah. (with no apparent reason for that) Ops.

`Observer`: Try once more.

Evaluator: (clicks the "Play" button at 72s, and the chord now plays OK).

`Observer`: Do you think some note is missing, some note is wrong?

Evaluator: Yes. I can't hear this (points with the mouse to the top note).

Evaluator: The top one. Yes, I think it is a matter of the system. I will bring the headphone (set) for us to check. I think it will be much more appropriate.

Evaluator: Yeah. Right. Cheers (while he waits for the headphone set, he plays the chord four times between 100 and 120s, and tries to insert the already existing C_5 at 124s).

`Observer`: (returning with the headphones) So, we can talk about technicalities after the experiment. (connect the headphone to the workstation) Perhaps I need to check if the audio control is acting upon the headphones (uses the mouse to bring the audio control to the screen and makes sure the headphone is selected). OK?

Evaluator: (with the headphone, he plays twice more at 153 and 160s) I don't hear that top note, I have to say.

`Observer`: OK. I'll check this.

Evaluator: (incomprehensible) once more.

`Observer`: Try to put a wrong one.

Evaluator: Perhaps let's do this (tries the failed insert of the note D_5 at 167s, and then undoes the insertion of the C_5 at 169s, inserts and deletes it again at 174s and 177s and insert the B_4 at 174s).

Evaluator: (plays the chord with seventh at 182s, and acknowledges that he is hearing it) OK.

`Observer`: Yes, it is being played.

Evaluator: OK.

`Observer`: I need to create a volume for individual voices. I was already thinking about it. To highlight a particular...

Evaluator: (changing the top note for D_5 and playing the chord at 192s) OK. I see. (after returning to the original C_5 on the soprano) Right, OK. Yeah. It's there.

---

[2]This seems to be related to the software sound synthesis process, and never happened before during the development or piloting, or later, after the study was run.

`Observer`: Where are we? So, insert, delete, you tried the "Play" button. Now, we are moving... We have a sequence of a chord only, so you are attempting to move to the next one and the system will check if it is correct or not when you click on the "New".
Evaluator: (clicking on the "New" button at 231s) So, if I go there. (without reading the feedback) Then "Next" exercise.
`Observer`: So, hm, hm.

Task 2

Evaluator: Now I have to write chord V in G major.
`Observer`: That's it.
Evaluator: (insert three correct notes).
Evaluator: (while inserting the wrong note at 17s) Ops. (deletes the wrong note and inserts the right one before playing the D major chord at 22s) Right.
`Observer`: So, you know how to construct. I think you haven't practiced the "Undo" button.
Evaluator: Oh, yeah (tries to insert the existing $F^{\sharp}_{5}$ and undo at 41s the previous insertion; insert, and undo at 47s, a wrong note; insert failed at 48s).
Evaluator: (undoing at 50s a deleted note) Ops. (uses the "Undo" button twice more). Oh, I see. OK.
Evaluator: (inserts the new alto and soprano notes at 61s and 63s, modifying the original chord, and plays it at 66s). Good.
`Observer`: So, we can move to the third task.
Evaluator: OK.

Task 3

Evaluator: Chords I – V – I in B flat.
`Observer`: Yeah. Now, I think it is a good idea for you to read this bit (shows page 8 of the handout), that describes a mechanism that you haven't used yet fully.
Evaluator: (reading the handout) After finishing the construction of a chord, click on the "New" button" to move to the chord immediately to the right. (continues to read quietly).
`Observer`: You need to take a look at the next page as well.
Evaluator: (reading the last sentence of page 8 of the handout) use the "Move" button... OK (turns the page of the handout).
`Observer`: (giving an explanation of the "Focus" mechanism) Figure 14 is after, the effect after clicking on the "Move" when you are in the third chord of the sequence, and then you can choose any other chord for you to return back. And in this case (shows Figure 15 in the handout) we are returning to the first one, and

then you can modify notes using the same mechanism that you used previously. OK?
Evaluator: So, B flat. (starts inserting the first note) Right. (inserts of the other notes, presses the "New" button at 86s and reads message on screen) Chord I not well formed.
`Observer`: Hm.
Evaluator: (realising the chord was not according to the handout) Oh, yes. Good. Yes (apparently agreeing with the system's analysis – and refusal of acceptance – of the chord with a double fifth). Very good. Very good.
Evaluator: (corrects the chord and press "New", having the chord accepted) Yeah. Excellent.
Evaluator: (while constructing the second chord, pressing "New", and constructing the third chord) OK. OK.
Evaluator: (after clicking on the "Move" button at 158s) So, now if I click on a box. (selects the second chord) OK. I see.
Evaluator: (clicks the "Undo" button at 174s, returning to the third chord of the sequence) OK.
Evaluator: (clicks the Move button at 182, selects again the second chord of the sequence, modifies the second chord from 190s to 201s, clicks on the "Move" button twice at 204/206s and reads the chord analysis on screen) Chord V not well formed.
`Observer`: According to the handout you cannot have more than one octave between the top three voices.
Evaluator: Very good. Very good.
`Observer`: In fact some chords were not yet coded, but most of them, the most structured, I mean (are coded).
Evaluator: OK. Good. (modifies the top notes of the second chord from 219s to 225s, presses the "Move" button at 227s, selects the third chord at 231s and plays the sequence at 234s) OK.
`Observer`: So, I think we are now moving to the last one. You are taking less time than I was expecting. We can create new sequences, if you like...
Evaluator: (laughs)
`Observer`: (laughs) ... for you to play a bit. But that's good news, in fact.
Evaluator: (after pressing the "New" button, and before pressing the "Next Exercise" button) Next exercise.

Task 4

Evaluator: OK. I – iii – V – I in the key of C. OK. (inserts four notes for the first open position chord) OK (presses "New" and insert the first note of the second chord at 20s).

Evaluator: (thinks a bit after the last insertion) Hm. I wanna to choose to do that alteration (using the "Undo" button five times from 298 to 302s, removes all inserted notes except for the root of the first chord, and insert three notes, constructing a close position first chord). OK (presses the "New" button).
Evaluator: (presses the "New" button, inserts the first note of the second chord at 53s, thinks a bit, inserts the second note at 59s, thinks a bit more, and inserts a wrong note at 68s) Ops.
Evaluator: (delete the wrong note at 69s, inserts the soprano note at the alto note at 72s) OK.
Evaluator: (presses the "New" button at , inserts the first note of the third chord at 84s and a wrong note at 86s) Ops.
Evaluator: (undo the last insertion at 92s, constructs the third chord, presses the "New button) This is the most boring harmonic sequence I've ever seen.
`Observer`: I agree with you.
Evaluator: (after constructing the fourth chord, presses "Move" focus at 118s and selects the third chord at 123s) OK (plays the sequence at 125s and 133s, showing his satisfaction with it).
`Observer`: To finish or you press "New", or "Move", or...
Evaluator: (presses the "New" button, moving to the fourth chord, but the task was not finished because there was a need to press "New" again, and after the "Next Exercise" button) OK.
`Observer`: Yeah. Cool. Much less time than I was expecting. I think we can now check the interview...
Evaluator: OK.
`Observer`: ... just to collect some feedback from you, your impressions in using the system. If we have time after that we can perhaps (incomprehensible) a little bit more (incomprehensible).
Evaluator: OK.

2 Questions (Semi-structured Interview)

1. `Observer`: How easy did you find in using the left button of the mouse to insert notes, in the scale from very easy to quite difficult?
   Evaluator: Very easy.
   `Observer`: Taking into account the target group, might the answer be different for users in the target group, very beginners?
   Evaluator: Ah, I think very easy.

2. `Observer`: Hm, hm. A similiar question: how easy did you find using the right button (of the mouse) to delete notes?
   Evaluator: Yes, easy.
   `Observer`: Easy. And regarding the target group?

Evaluator: Yes, I think that's once you find it once it's quite easy to find it again. Once you find the place for an early once.
`Observer`: I noticed that in some points you have some difficulty in delete and used the Undo.
Evaluator: There were two places, I think. (incomprehensible)

3. `Observer`: Did you use the "Undo" button (to delete an inserted note)?
   Evaluator: Yes.
   `Observer`: Did you prefer this to using the delete mouse button?
   Evaluator: No, because... Well, I think these are different contexts. If you put something in the wrong place then it's easy to remove it instantly (using the delete mouse button). But if you put all of your notes in and you want to change what you have done, then "Undo" is easier.
   `Observer`: And in relationship to the target group, do you think they will find...
   Evaluator: I would say that both options are useful.

4. `Observer`: OK. The next question deals with the same button but in another context. Did you use the "Undo" button to insert a deleted note?
   Evaluator: Did I use the "Undo" button...
   `Observer`: "Undo" button to insert a just deleted note?
   Evaluator: To insert a just deleted note.
   `Observer`: If you delete a note and Undo (it) you will insert it.
   Evaluator: No. I didn't do that.
   `Observer`: So, in this case, did you understand how the "Undo" button works?
   Evaluator: Yes.
   `Observer`: But is not so intuitive this particular situation.
   Evaluator: Yeah, that's true.
   `Observer`: Regarding the target group, what do you think they will find this particular... Undo an inserted note, sorry, undo a deleted note, in such a way that you will insert.
   Evaluator: Well, I think that the Undo button is quite a common occurrence in other software like a "Back" button in a Web browser or the Edit or Undo buttons in several music packages. So, I think that the idea is just kind of reversing back through things you have recently done. It's quite common.

5. `Observer`: OK. The "New Focus" button moved the focus to the chord immediately to the right of the current one. How easy did you find this to use?
   Evaluator: That was easy to use.
   `Observer`: Not very easy.
   Evaluator: Very easy, yeah.

`Observer:` Are there alternative ways to move?
Evaluator: Hm (thinks for 10 seconds). Well, I suppose that a potential confusion is that the button "New" gets used to a number of different things. Its gets used to move you to the Next exercise, for example. And also there is a potential semantic misconception, perhaps, in that 'New" tends to imply something that is not here rather than next, which implies moving onwards. But once you get the hang of it, of course, that is fine but,...
`Observer:` Basically you are saying that the name perhaps is not appropriate.
Evaluator: I wonder if...
`Observer:` "Next" could be more appropriate.
Evaluator: "Next" might be more appropriate.
`Observer:` OK. Let's talk about these issues when I (incomprehensible). Did you always note the feedback given, after clicking the "New" focus?
Evaluator: No (laughs).
`Observer:` (laughs). It is very hard.
Evaluator: If I'm honest the size of the window and the text that appears makes it less evident to the eye compared to the size of the window of the music staves. I didn't find that it kind of attracted my attention maybe sufficiently. Because there was at least once where I – that time when you gave me the rule that you have to keep in the octaves – where I really did noticed.
`Observer:` OK. It is just a matter of perhaps enlarging the (text) window and enlarging the font (size) as well.
Evaluator: Yes. That's right.
`Observer:` I was about to do this, but yesterday I did not have time to do. And also this resolution is bigger that the one I am using.
Evaluator: Right.
`Observer:` Perhaps changing both.
Evaluator: One thing that might make things easier for a beginner is if the cursor changes its form when you are positioning it on a line or on a space (of the musical staves).
`Observer:` I see.
Evaluator: So you can see: Oh, I'm over a line, so I can click. Oh, I'm over a space. I mean, you can pretty much see this with this resolution but it is not so hard to change the cursor.
`Observer:` I don't think so (the evaluator meant that it is easy to change the cursor shape).
Evaluator: That will just make you absolutely clear of what I am talking about.
`Observer:` sound like this will make a difference, a real difference (incom-

prehensible) completely aware of where are you. I tried to be very careful in the positioning of the cursor to make...
Evaluator: For example, when you enter notes in Finale and you go below the stave you get the ledger lines. So, as you move the cursor down the ledger lines appear and if you move a little further then the ledger lines from the second stave appear. So, you actually know where about you are. And I do think this is quite intuitive.
`Observer`: Have you noticed the working of the ledger lines?
*Evaluator:*Yes.
`Observer`:If you click, the ledger lines will be highlighted. Below the note if it is below the stave, or above the note if it is below the stave.
Evaluator: I think that is quite clear. It is just the positioning.
`Observer`: So, it sounds like a change of shape of the cursor it will be enough for a beginner to be confident where is he, and this will avoid this kind of mistake of clicking on a neighbour note.
Evaluator: Yes.

6. `Observer`: Did you use the "Move Focus" button to move the focus backward in the sequence to chords?
Evaluator: Yes
`Observer`: Having moved backwards, how easy was it to change notes?
Evaluator: It was easy to change notes. I would not say it was very easy, but it was easy.
`Observer`: I noticed that you tried to Undo thinking that you were undoing an inserted note (at a different focus) but in fact you undid the move focus itself and you realised that the working of the Undo. How did you move forwards again after changing things?
Evaluator: So, I clicked, I physically clicked on one of the boxes.
`Observer`: OK. The move focus again. Because the New button simply will moves to the neighbor (chord) on the right.

7. `Observer`: Did you use the Play button?
Evaluator: Yes.
`Observer`: Did you find it useful?
Evaluator: Yes, absolutely.
`Observer`: Why?
Evaluator: Because it allows you to hear what you have just done. I think that there is some problem with the clarity of the sound, and the two things that occurred to me are: I don't know what you are using to synthesise the sound, but the tail of the reverberation is quite long. It could actually be a little shorter. And then somehow the balance of the notes is probably equal and that created problems particularly at the beginning (when) I

couldn't hear the top note because the harmonics were already present (incomprehensible). There are ways to get around that.
`Observer`: So, we are already in the (section of) suggestions for improvements. My original idea was to put a kind of panel with individual volume (controls) for each one of the voices.
Evaluator: Yes, that might be a good idea.
`Observer`: So we can really highlight one and hide the others.
Evaluator: Are you using an off-the-shelf synthesiser or did you make it yourself?
`Observer`: I am using timidity for Unix, (which) is a soft synth. So I need to generate the midi file and play the midi file using timidity. That was the only way I found in this Unix platform. But it is working, and I need to find a better sound regarding this reverberation.

Transcription of Basic Information Collection,
Evaluator Interaction and Semi-Structured
Interview for the Empirical Study on

A Harmony Teaching Environment Interface

Participant B: Stephen Doughty

Date: 03 April 2001

1 Basic Information

1. `Observer:` Describe your background in music.
   Evaluator: I am a professional musician.
   `Observer:` But, I mean, degrees and ...
   Evaluator: I have Bachelors and Master's degree both in Music.
   `Observer:` Masters as well. Bachelors and Masters.
   Evaluator: And diplomas. A few diplomas.
   `Observer:` A few diplomas. A few?
   Evaluator: Three.
   `Observer:` And this Master was in Composition, or..?
   Evaluator: In performance as a accompanist.

2. `Observer:` OK. And about the music styles and composers that you are used to listen to, could you please describe....
   Evaluator: Classical music. (pause) Not so many modern composers, but most of the rest.
   `Observer:` Most of the rest? Classical, romantic, ...
   Evaluator: Oh, I see. (pause) Let's say classical and romantic composers, perhaps.

3. `Observer:` And about compositions, are you used to compose?
   Evaluator: Not really, no. I mean, small, little small little things, nothing major. Very short choral pieces, perhaps.
   `Observer:` Choral pieces.
   Evaluator: Short. Very short (laughs).

4. Regarding your computer skills. How do you classify yourself as a computer user?
   Evaluator: Amateur.

5. `Observer`: And what about using these devices like sequencers, recorders, notators, ...?
   Evaluator: I use Sibbelius, the music printing software.
   `Observer`: Music printing.
   Evaluator: Yeah. And I don't use sequencers or anything like that.
   `Observer`: OK, but you use notators.
   Evaluator: How could you describe you in this scale (shows the scale)?
   `Observer`: I don't use a sequencer, but I use Sibelius. I suppose you can put me as proficient in Sibelius.

`Observer`: OK. That's it from the "Basic Information". I think now we can start taking a look in this (shows the handout), you already did a bit. You already know about diatonic scales (shows page 2 of the handout), I presume (laughs).
Evaluator: I hope so (laughs).
`Observer`: Nothing new in this page (page 2 of the handout), I think, and the next page (page 3 of the handout) deals with the basic constraints of Schoenberg (incomprehensible). We need to put a context that this tool is intended for very beginners in the study of harmony, so.
Evaluator: Sure.
`Observer`: You need to observe these constraints basically when you are interacting with the interface, but I think it will be very easy for you. The most restrictive one is the bass always in the root,...
Evaluator: Always in the root, right.
`Observer`: Always in the root at least during these interactions, and following this, three final steps for connecting chords: starting with the bass, followed by the common tones between the chords, and after that fill what is missing.
Evaluator: Common tones mean the same note?
`Observer`: The same note. All connections (here) deal with chords having common tones. (These are) the very first exercises from Schoenberg, from his curriculum. That's an example of (a) sequence of chords (shows sequence in oage 4 of the handout).
Evaluator: OK.
`Observer`: I think it is time to start interacting with the interface, following the guidelines in the handout. The handout describes (them), is almost a user guide for it.
Evaluator: (reading the instructions at the handout) Click on the "File" menu (clicks on the "File" menu and selects the option "New"). (reading the instructions on screen) Insert your first name (type his name). (reading the instructions on screen) Good morning, Stephen (laughs). ... "Next Exercise" button.

`Observer`: Before interacting, now we have something more to read, basically the mechanism for inserting and deleting notes and also the Undo mechanism is described...
Evaluator: (reads aloud, but almost incomprehensably) the description of the mechanisms at the handout) Right. OK.
`Observer`: And the next page I think there is something about the "Play" (button). Oh, no. It is to move to the next exercise.

`Observer`: After constructing, if the chord is wrong, if you click on the "New" button, the interface will provide you with some feedback about what is wrong in the chord. But if it is right, you move straight away to the next exercise. So perhaps is good for you to get used to (in using) the insert and delete (mechanisms), Undo mechanism before clicking the "New" button.
Evaluator: OK.
`Observer`: You can click on the "New" if it is a wrong chord, and you will receive the feedback.
Evaluator: So, you want me to put a chord in the page?
`Observer`: Yeah.
Evaluator: In C major, presumably.
`Observer`: Yeah. In the first degree.

Task 1

Evaluator: (inserts the first note at 84s, and then the wrong note at 91s) Ops.
Evaluator: (corrects the wrong note using the "Undo" button at 94s, inserts the other three notes, and plays the chord at 107s)
`Observer`: Perhaps (we can put) a little bit louder.
Evaluator: That's OK.
`Observer`: We have a headphone (set) as well, if you ...
Evaluator: That's OK. (reading incomprehensibly from the screen) and then I click on"New"?
`Observer`: I think you haven't used the mechanism for..
Evaluator: (incomprehensible) OK.
`Observer`: Of course, you've used the delete one.
Evaluator: I used the "Undo".
`Observer`: Ah, the "Undo? Ah, you used the "Undo" to delete. You can delete using the right button (of the mouse) as well.
Evaluator: All right. (realising that the chord is missing a note) And I missed a note as well, I missed the G out.
`Observer`: The G?
Evaluator: I missed the G out.
`Observer`: You tried to click on a C, but you clicked on a B, is that right?

Evaluator: So, ...
`Observer`: Right button, you can delete.
Evaluator: (delete a note using the right button at 154s and inserts the missing G at 155s).
`Observer`: That's it.
Evaluator: Right (plays the chord at 155s).
`Observer`: (incomprehensible) That's it. So, you used the undo, you used the delete, you can move to the next chord, if you like, next exercise.
Evaluator: "New" (button)?
`Observer`: New. "New" (button) provides feedback about the chord. (reads the feedback on screen) So, it is an open root position chord, and the root is on the soprano as well. The sequence is made up of only one chord so, that's (incomprehensible).
Evaluator: (clicks the "Next Exercise" button)

Task 2

`Observer`: (noticing that task 2 were already selected) The same task, but a different key and a different degree.
Evaluator: So, chord V of that key. Is that right?
`Observer`: Yes. Do you think it makes sense?
Evaluator: Yes. Do I do ideally want closed chords or open chords?
`Observer`: You are free to choose whatever you want. Some of them, the open ones, perhaps are not completely coded within my system, but most of the traditional ones, with one note free in the middle of adjacent notes, all of them I think are properly coded in my system.
Evaluator: (inserts the four notes of the chord, starting at 50s, and plays the constructed chord at 63s)
`Observer`: Do you think something is..? *Evaluator:* No. That's OK.
`Observer`: (checking the chord) Yes. That's OK. Absolutely. So, you are not making mistakes, you are not getting feedback from wrong chords, but you will have the opportunity in the next few sequences. So, I think you are already used to the mechanisms of insertion, deletion of notes, and feedback, and also messages for moving to the next ...
Evaluator: (clicks the "New" button at 81 s, then the "Next Exercise" button)

Task 3

Evaluator: (reading the instructions on screen) Construct the sequence of chords shown.
Evaluator: (constructs, instead of the requested chord **I** in the key of B flat, a g-minor chord from 13s to 21s) How do I move to the next chord?

`Observer:` There is a small description here (shows page 8 of the handout). It is the "New" button again, the "New" focus. We have a focus mechanism to move back as well, using the "Move" (button). So, the "New" button will theoretically move to the next chord.
Evaluator: (clicks the "New" button, and reads the information on screen) Chord I not well formed.
`Observer:` (without giving a hint of what was wrong) Yeah.
Evaluator: (reading the information on screen) Note G natural in the bass is not part of chord.
`Observer:` Yeah.
Evaluator: (realizing he constructed the wrong chord) Oh, Sorry. I've put G minor. Sorry, sorry.
`Observer:` That's the aim of this study. To interact ...
Evaluator: (incomprehensible) g minor. sorry.
`Observer:` Did you noticed about the feedback?
Evaluator: Yes, hm,hm. Sorry. Let's start again.
Evaluator: (corrects the chord from 75s to 89s, press the "New" button at 92s, and reads the **previous** message) Chord I not well formed.
`Observer:` That was the last one (message).
Evaluator: Phew.
`Observer:` If the chord is right (as it is the case), you move to the next one.
Evaluator: (constructs the second chord from 106s to 111s, presses "New" at 114s, and constructs the third chord from 118s to 123s)
`Observer:` Perhaps listening to the sequence.
Evaluator: (presses the "Play" button at 129s)
`Observer:` Very, very, very simple one. But, that's it. If you can move, if you like... I perhaps suggest you to try to move back the focus, change the chord, because we are trying to evaluate this mechanism.
Evaluator: OK (clicks on the "Move" button).
`Observer:` After that, you can click on any of the rectangles and you can return. After, if you change notes, you will be stuck up to the point that the chord is correct again.
Evaluator: OK. Do you want me to try to put an altered note?
`Observer:` You can try, if you like. Or you can modify for another inversion.
Evaluator: But the root is always in the bass.
`Observer:` But you can change the top notes, the formation, if you like.
Evaluator: All right. OK. (selects the second chord) I'll try to do something. (modifies the notes from the second chord from 179s to 184s)
`Observer:` It's pretty cool.
Evaluator: (plays the sequence twice at 189s and 195s)
Evaluator: A natural, hm, ...

`Observer`: No, I think it's OK. You haven't tried to move again, so there is no feedback yet about the well formedness of the chord.
Evaluator: Right.
`Observer`: You have two ways of moving again: or using the "Move" button or using the "New" (button) to move to the right one step.
Evaluator: Right. So that goes to...(clicks on the "New" button, receives the positive feedback from the system and shakes the head agreeing with it)
`Observer`: If it is right you will receive the feedback and move to the next one. Usually, I think that's the way most interaction will be made. If you change inversion of a chord, or the formation of the notes, you will be forced to move the next one as well, usually, if you want to try to follow this "law of the shortest way". So, the "Move" button gives you freedom to go to any worked chord, not an unworked chord, if there was (any), but this is not the case in this sequence.
Evaluator: (navigates between the chords as the observer speaks, using the "New" and "Move" buttons from 224s to 262s).
`Observer`: So, if you like to move to the next exercise, it is just a matter of finishing the sequence.
Evaluator: (clicks on the "Next exercise" button)
`Observer`: Yeah.

Task 4

Evaluator: C major, not E minor.
`Observer`: C major (laughs). But the capital roman I think I can enlarge it a little bit, perhaps.
Evaluator: Do you want me to do something un.., un..
`Observer`: Unusual? It's up to you.
Evaluator: I'll try this. (inserts the wrong note at 24s) Ops.
Evaluator: (deletes the note at 26s, reinsert and deletes again the wrong note at 27s and 28s respectively; inserts notes part of the triad from 29 to 36s, presses the "New" button and reads the message on screen) Chord I not well formed. Please check the inversion.
`Observer`: This message needs to be improved a little bit, to detect..., but in fact the inversion is not completely right. You do not have.. Oh, no, you have all the notes (of the triad). Do you think this chord is acceptable?
Evaluator: No. Not really. No. It does say in the thing (handout), it says ...
`Observer`: That notes cannot be spaced more than an octave. But you have exactly an octave in here (points to the octave spacing between the top notes), so is within the constraints, so...
Evaluator: Yeah. Does it not allow it because is so far apart?
`Observer`: In fact I haven't coded this particular formation of chord, if you like, but I think I need to. What do you think about it? Do you think this chord is

a...?
Evaluator: No. Is not particularly a ...
`Observer:` You don't like this chord. I see. It was good not solving it.
Evaluator: I would like to change that one (inserts E_4 in the bass stave not accepted at 97s, and deletes E_4 in the bass stave at 98s) and put it at there (inserts G_4 in the bass stave at 99s).
Evaluator: And that one and put it at there (deletes G_4 and inserts C_5 in the treble stave at 102s). Ops.
`Observer:` Hm,hm. That's an open one.
Evaluator: And change that one (deletes G_5 in the treble stave at s) and put it at there (inserts D_5 in the treble stave at 106s). Ops.
Evaluator: (chord changing sequence of actions: tries twice to unsuccessfully delete E_5 at 108s; tries unsuccessfully to insert the same E_5 at 109s)
`Observer:` They are just beside each other (notes C_5 and D_5 on screen). This situation I hope it is not easy to happen in most of these exercises.
Evaluator: (deletes C_5 at 111s and D_5 at 113s; inserts F_5 at 114s and deletes it at 116s; and finally inserts E_5 at 117s; deletes C_5 failed at 119s and inserts C_5 at 119s) Let's try that.
`Observer:` That's it. It should be fine.
Evaluator: Do I need to do something to (tries to unsuccessfully insert D_5 at 131s)?
`Observer:` You are trying to insert notes, because each rectangle accommodates only two notes. So, if you are trying to insert (a note) you receive the feedback informing (incomprehensible) that you are allowed to use only two notes, so you are not able to (insert notes).
Evaluator: So, is that OK, then?
`Observer:` I think so. Just click on the "New" button and you can get the feedback.
Evaluator: (clicks on the "New" button at 151s) Oh, I see. Right. OK
`Observer:` That's it.
Evaluator: OK. OK.
`Observer:` (constructs the second chord from 161s to 174s; presses the "New" button at 178s, moving to the third chord; constructs the third chord from 185s to 193; presses the "New" button, and breathes after receiving the message "Chord not well formed)
`Observer:` (analysing for a while the constructed chord) Hm, hm. Is this an acceptable chord?
`Evaluator:` I would thought so, yeah. Is it because that line leaps (shows the tenor leap) as opposed to keep the common...
`Observer:` Is it because I haven't coded this particular formation. As I said, the ones I've coded is (are) the closed ones, and the open ones when we move one

chord (note) to the top (better saying, when the alto note of a closed chord is transposed and octave higher) ...
`Evaluator`: OK.
`Observer`: ... so we have only a (single) free empty tone in the middle (of the top three voices).
`Evaluator`: Right.
`Observer`: I think you have two in here, is that right (points to the spacing between the alto and tenor voices)? You have the G.. Ah, here (points to the spacing between the soprano and alto notes) is a close (position chord) and in here (points to the spacing between the alto and tenor notes) you have an open (position chord). You are mixing the close and open position in just one chord.
Evaluator: All right.
`Observer`: But, yeah. You are mixing (the positions in just one chord). But you think this is an acceptable chord.
Evaluator: I would thought so. Yeah. The reason I've done that, because this chord is acceptable and according to the rules you have a common note here, without big leaps. So, I wonder if...
`Observer`: This one (points to the G note on the tenor voice of the second chord) is a G, is that right?
Evaluator: Yeah.
`Observer`: So, the G is a common (note) as well.
Evaluator: Yes.
`Observer`: You are supposed to keep it.
Evaluator: But.. All right, OK.
`Observer`: Do you agree?
Evaluator: Yeah. That makes sense (modifies the tenor note and presses the "New" button, moving to the fourth chord).
`Observer`: So, the chord (the previous one) is acceptable.
Evaluator: (noticing that the modified chord was accepted) Right. OK.
`Observer`: I need to perhaps instead of not enabling completely the user to move, perhaps providing a warning, saying: "oh, this is..."
Evaluator: OK. It liked that one. It liked that one.
`Observer`: This (points to the third chord on screen) chord?
Evaluator: Yes.
`Observer`: And this sequence (still pointing to screen).
Evaluator: OK.
Evaluator: (constructs the fourth chord from to; presses the "New" button at 321s)
`Observer`: Yeah.
Evaluator: OK.
`Observer`: You have finished it.
Evaluator: OK.

`Observer`: You finished the task completely.
Evaluator: So, are you going to write, for example, the reason this chord wasn't accepted?
`Observer`: Hm, hm.
Evaluator: There would be a feedback from the computer to say why?
`Observer`: Yeah,I intend to do this, but I am analysing in a vertical way currently. I am not analysing the connection.
Evaluator: Right.
`Observer`: Probably this one (feedback) should be given, because you were not keeping the same note (G_4).
Evaluator: Right. Because at the very beginning one of the criteria was to connect notes together.
`Observer`: Yeah. But I asked you to perform the tasks taking into account this (the criteria) but the feedback is not being provided by the current system.
Evaluator: OK. Next. (press the "Next Exercise" button and reads part of the message on screen) Thank you ...
`Observer`: (laughs) So, I think it was a very good interaction. Now it is time for the interview, in order for you to give ne the your impressions about the (looks for the "Semi-structured Interview Sheet")...

2 Questions (Semi-structured Interview)

1. `Observer`: How (easy) did you find using the left button of the mouse to insert notes in chords, from the very easy to the quite difficult range?
   Evaluator: It was quite easy. Quite easy.
   `Observer`: Taking into account the target group, that's the very beginners in harmony, might the answer be different for this kind of use (of the button)?
   Evaluator: Probably not, because most people are very familiar with computers, generally, so using the mouse would be quite natural, I think.

2. `Observer`: And what about the right button (of the mouse), how easy did you find using it to delete notes?
   Evaluator: Fine, yeah.

3. `Observer`: Very easy?
   Evaluator: Yes.
   `Observer`: Very easy as well.
   `Observer`: And about the answer..., the same answer for the target group.
   Evaluator: I would think so. Yeah. Just because of beginners in harmony won't be beginners in using a computer, so...
   `Observer`: I thought this as well.

4. `Observer`: Did you use the "Undo" button to delete an inserted note?
   Evaluator: I did the the first time. Subsequently I found easier to use the (right button of the) mouse.
   `Observer`: Ah, OK. You already gave me the answer to the next question: Did you prefer this to using the delete (mouse button)?
   Evaluator: No.
   `Observer`: You preferred the "Delete" (button).
   Evaluator: Yes, on the mouse, yeah...
   Observer: And about the target group, do you think the answer would be similar?
   `Observer`: I would think so. To use the "Undo" (button) puts an extra step into the thing, and if you just use the mouse you don't have to. You know, it's there, it's quicker.

5. `Observer`: Did you use the "Undo" button to insert a deleted note?
   Evaluator: No.
   Observer: (repeats what the evaluator said) No. Because this feature is also implemented in the system.
   Evaluator: Right.
   Observer: Did you understand how the "Undo" button works?
   Evaluator: Yes.
   Observer: And about the answer regarding the target group, do you think the answer would be similar?
   Evaluator: Yes. I would think so.

6. `Observer`: The "New Focus" button moved the focus to the chord immediately to the right of the current one. How easy did you find this to use?
   Evaluator: Very easy.
   Observer: (repeats what the evaluator said) Very easy. Are there alternative ways to move?
   Evaluator: (repeats what the observer just asked) Are there alternative ways to move?
   Observer: Yeah.
   Evaluator: What do you mean by that?
   Observer: Is it possible to move within the sequence of chords using another button or another mechanism? In fact we are asking (if there is another way) to move to the right of the current one.
   Evaluator: I don't know. Using cursor keys, tab perhaps, I don't know.
   `Observer`: In fact I haven't implemented this by means of the keyboard. You can move to the right within a sequence using the "Move" button, that what I was trying to say ...

Evaluator: All right.
`Observer:` ... but if you are in the right hand side of a sequence, a not completed one, you will not be able to move to the right unless you use the "New" focus (button).
Evaluator: I was slightly confused by the term "Focus" and the term "New".
`Observer:` I see.
Evaluator: Perhaps at the end of an exercise like this "New" would refer to moving to the new page whereas within a sequence in itself and having move left and move right, perhaps,... (incomprehensible) the word "Move" would imply to moving the rectangle while "New" implies a new page, a new exercise, a new whatever. You presumably mean the word focus to refer to the focus of the rectangle.
`Observer:` Yes.
Evaluator: Is that what you mean?
`Observer:` Yes. Is exactly what I mean. Perhaps using the "Next" instead of "New"?
Evaluator: Yes. Perhaps. Normal computer terminology uses "Next", or "Back", perhaps.
`Observer:` But this is little bit more complex than back because you can move to the right as well.
Evaluator: The "Move" button moves to the left, though.
`Observer:` No. You can move to the right as well. If you click on the "Move" in this situation (shows the rightmost, and focused chord of the worked sequence) for instance, select another one (at the left of the current chord), then you can click on the "Move" again to return to the right. Because you will produce the rectangles you can select.
Evaluator: So, they go around in a circle then?
`Observer:` No. I think after the interview I will show you the ...
Evaluator: How is on this chord and I click on the "Move" (incomprehensible).
`Observer:` You can click, after clicking on the "Move" button, you click on this rectangle that will be highlighted, all of the rectangles of the worked chords will be highlighted.
Evaluator: All right. OK. Right. OK. OK.
`Observer:` It seems that perhaps moving the denomination of..., the name of the "New" button to "Next" would be enough.
Evaluator: Perhaps. You have "New Exercise" and "Next Chord", perhaps.
`Observer:` (taking notes at the interview sheet) New exercise and next focus.
`Observer:` Did you always note the feedback given?
Evaluator: Yes. There was more information here that I was expecting. Everything I did whether was on a stave or not would come up here (shows

the message area on the screen).
`Observer:` So, you think we are having too much information in the screen.
Evaluator: Perhaps ... Is it possible to make the current information in bold, and the ex- information in lighter font. Is that possible?
`Observer:` Yes, of course.
Evaluator: So your immediate eye is immediately drawn to the current instruction.
`Observer:` Yes. That's an excellent idea.
Evaluator: As we had a few minutes ago, when I read the entire screen (incomprehensible) the last instruction, perhaps.
`Observer:` In fact this window is being developed, and your information is very useful for improving the communication with the user.
`Observer:` How useful did you find the feedback?
Evaluator: It was useful in that it told me that I was doing something which it didn't agree with it, but I would prefer to have it told me why it didn't agree with it.
`Observer:` A full explanation.
Evaluator: Yeah. Just getting the instruction "This chord is wrong" is one thing, but ....
`Observer:` This chord is wrong because of ...
Evaluator: Because of. Yes. Because this note is not a common (one), or this note should be common, or whatever.
`Observer:` I see.
Evaluator: Too bigger leap, too bigger gap, perhaps, followed up for the criteria.
`Observer:` It's useful but it's missing information, somehow.
Evaluator: Could be. Yeah. Because a beginner would want to know why that chord wasn't right. So, it would come up "error" , or whatever, and "because" and then you can know the next time.
`Observer:` OK. Very useful suggestion, as well.

7. `Observer:` Regarding the "Move Focus" button, did you use it to move the focus backward in the sequence?
Evaluator: Yes.
`Observer:` Having moved backwards, how easy was it to change notes?
Evaluator: Very easy.
`Observer:` (repeats what the evaluator just said) Very easy.
Evaluator: To remind me, when you press the "Move" button, did I highlight all of them?
`Observer:` Yeah. All of the worked chord.
Evaluator: Yeah. But not individually. Then you have to click on an individual one.

`Observer`: How did you move forwards again after changing things?
Evaluator: Hm, "New".
`Observer`: Yes, I think it was. Otherwise you have perceived the thing I was talking that (using) the "Move " (button) you are able to move to the right as well.
Evaluator: Ah.

8. `Observer`: Did you use the Play button?
Evaluator: Yes.
`Observer`: Did you find it useful? And why?
Evaluator: (laughs) It was useful because it played back the chords I had written. The balance of the chord was interesting in the previous page. The top part of the chord was not as loud as the rest of it.
`Observer`: I agree with you.
Evaluator: So, I had to listen to it twice to make sure that I was actually playing what was on the page.
`Observer`: I will provide you with more information after finishing the interview about this. You are not the very first person to say about the same think. I can give you some technicalities and details later on.
`Observer`: Any comments, problems or suggestions for improvements? I think you already did so somehow,so... But do you have something in mind that might solve this problem, bypass this problem somehow of not bewing able of perceiving the top note? It seems that that's is a main difficulty, is that write?
Evaluator: No. I am not sure if it so much of a difficulty. But when I played the chord back the chord didn't sound as I expected it to. Not all the voices were equally balanced.
`Observer`: Hm, hm. Which way do you think it would be good to provide this king of balancing?
Evaluator: Just make sure that all the parts are clear, clear to be heard.
`Observer`: Probably the user will want to adjust individual voices. What do you think about a mechanism that (through which) you can control the volume of each one of the four voices. Emphasizing, or...
Evaluator: Possibly, or perhaps a mechanism for highlighting only, say, inner parts, perhaps.
`Observer`: Hm, hm.
Evaluator: In regarding to connecting the voices, if I click on "Play" it will play all four chords, but specifically highlighting the inside parts so I could hear the connections, perhaps.
`Observer`: I see.
Evaluator: Perhaps two (incomprehensible). The average person would just want to hear the four chords played with equal volume.

`Observer`: Providing a mechanism is not that complicated from the technical point of view. I think I will do something taking into account these suggestions for improvements in general. So that's another good suggestion from you.

9. `Observer`: What would you expect to happen at the end of a task or exercise?
   Evaluator: Perhaps an invitation to move on to level 2, or whatever.
   `Observer`: To move to the next one.
   Evaluator: Or perhaps a resume of my mistakes. Or: you shouldn't do this, you shouldn't do that.
   `Observer`: That's another good idea.
   Evaluator: You know, if I made (incomprehensible) mistakes, for example "make sure the root of the chord is always in the bass".

10. Any other comments, problems or suggestions for improvements?

Transcription of Basic Information Collection, Evaluator Interaction and Semi-Structured Interview for the Empirical Study on

A Harmony Teaching Environment Interface

Participant C: Mário Lima Caribé

Date: 03 April 2001

1 Basic Information

1. `Observer`: Describe your background in music.
   Evaluator: I have a Bachelors in Composition by the University of Campinas in São Paulo, Brazil. I am finishing my Masters in Jazz Composition at Napier University. I am a professional musician for over twenty years now. I've written many pieces, arrangements,...

2. `Observer`: That's the next question. You have described your background: Batchelors and Masters of Science sic Music. We have some questions regarding the styles and other stuff as well. List the music styles and composers that you are used to listen to.
   Evaluator: I listen to everything. From classical to popular music to jazz (pause) to pop, everything. It has to be good, though.

3. `Observer`: OK. And about the music styles of your compositions, how would you classify them?
   Evaluator: My compositions are usually much more jazz oriented because they usually use a lot of improvisation. But they also feature heavy use of brazilian rhythms and they are heavily influenced by generally brazilian culture and brazilian music.

4. `Observer`: Now regarding the computer side of the story: How do you classify yourself as a computer user?
   Evaluator: I rely on computers quite heavily to work. I use notation software when I compose either on a guitar or on a piano, and I put it into a

computer and I orchestrate it and do all the instrumentation on a computer and print out the scores and individual parts.
`Observer:` So, we could classify you as an expert in using (the) notators.
Evaluator: I've been using notation programs for over 15 years.
`Observer:` Because of that you are using computer mostly, I presume.
Evaluator: Yes. From a certain point in the compositional process, I have been using the computer very, very heavily.
`Observer:` OK. So, I think we can say that, as a computer user, you are proficient and expert in notation programs.
Evaluator: Proficient, proficient.
`Observer:` Now I would like to ask you to read something, and after that you start the tasks.

Task 1

`Observer:` (in Portuguese, while the evaluator was filling the name with spaces, after selecting "File/New" from the menu) No, no. Without space.
Evaluator: (in Portuguese) Without space?
`Observer:` (in Portuguese) Yes. Without space. You can write only "Mario", OK?
Evaluator: OK. (Reading the welcome message from the program) Good evening, Mario. Thanks for taking part in this study. Please press the "Start Exercise" button.
Evaluator: (after pressing the "Start Exercise" button, he continues to read the instructions on screen) Construct a four-voice chord on the degree and major key shown and press the "New Focus" button when ready.
`Observer:` The idea in here is for you to practice a bit with the insertion and deletion mechanisms.
Evaluator: Right. So it's in (the major degree) C.
Evaluator: (while using the mouse buttons) Hum?
`Observer:` (after the evaluator constructed a chord) OK. You can try to play, if you want.
Evaluator: Yes. Play.
`Observer:` (while increasing the volume) We need to put a little bit louder.
Evaluator: All right.
Evaluator (after pressing the "Play" button and listening to the chord) Lovely.
`Observer:` So, you can also try the "Undo" mechanism.
Evaluator: Let's see. (incomprehensible)
`Observer:` Do you know what I mean?
Evaluator: Yes, it took (out) the last note
Evaluator: What if I press again the "Undo" (button)?

`Observer`: Try...
Evaluator: Oh. All right.
`Observer`: All the actions are in a stack, you know what I mean?
Evaluator: So, it goes back to the very first one.
`Observer`: Yeah.
Evaluator: OK. So, and if we want to put all them (the notes) back?
`Observer`: We don't have the "Redo" button.
Evaluator: OK. I have just to put them back. (while reconstructing the chord using the insert and delete buttons) Ops. Ops.
`Observer`: You can try to click on the B just for you to get a feedback from a wrong chord of the system. You click twice on the note B, so that's (incomprehensible).
Evaluator: Right. (after clicking twice) What's that?
`Observer`: You are clicking again on a note, trying to insert it again, but it already exists.
Evaluator: All right. (after a couple of mouse clicks) So, that's it.
`Observer`: That's it. And after pressing "New", is the only time when you get the full feedback from the correctness or not of the chord.
Evaluator: If I put a B here (point the mouse to B_4), what it is gonna to... (say).
`Observer`: You can try to receive the feedback from the system, just for you to check. Try to press "New".
Evaluator: (after inserting A_4 at 134s, the evaluator reads the feedback provided) Chord not well formed. Note A natural in the treble stave is not part of the chord. OK. But I can still hear it.
`Observer`: Yeah. All the time you are able to listen to what appears on the screen.
Evaluator: Excellent. (while substituting A_4 for B_4 156-158s) This is B. Ah, ah, OK (play). All right.
`Observer`: (noticing that the evaluator had deleted and re-inserted the B_4 from 172 to 175s) Try to "Undo" right now, just for you to check one thing.
Evaluator: All right. (click the Undo button once at 176s, removing the B_4 from the chord))
`Observer`: Twice. Try it again.
Evaluator: (after clicking again on the "Undo" button). All right! Let's try again (click on the "Undo" again). And again (click on the "Undo" again). So, it is coming back, tracing all my actions right from the beginning. OK.
`Observer`: So, I think you are already used to these mechanisms. You can press "New" using a right chord.
Evaluator: OK. (after pressing "New", the evaluator reads the feedback from the system) Chord I is an open position with the root in the soprano. This was the last chord of the sequence. Please press "Next Exercise".

Task 2

Evaluator: (reading the instructions on screen) Construct a four-voice chord on the degree and major key shown and then press the "New Focus" button when ready.

`Observer`: Yes.

Evaluator: (after a few clicks) Ahn, Ahn. (after a couple more of few clicks the evaluator pressed the "Play" button to listen to the chord). Ops. (realising that the constructed chord is not the one requested) That is not the chord I. You want the chord V in G.

`Observer`: That's it.

Evaluator: OK. (while using the mouse) Undo. Undo. Undo. Undo. Undo (actions from 37 to 39s. Hm. (while inserting a note) D. (after constructing a D major chord, and pressing play) OK.

`Observer`: That's the major chord. You can perhaps start constructing sequences. That's the next task.

Evaluator: Let me see. New. Focus new.

`Observer`: We don't have Focus (concept) at this stage as you have only one chord (to construct). But (in the) next exercise you will have it.

Evaluator: I was looking for the feedback from the program.

`Observer`: I see.

Evaluator: (after pressing the "New" button and reading the analysis of the constructed chord on screen) Chord V. close. fifth on the soprano. Ahn, Ahn.

Task 3

Evaluator: (reading the instructions for the new task on screen) Construct the sequence of chords shown.

`Observer`: Using the focus mechanism as well to move.... I would like to ask you to try the Focus button to return back in the sequence, at some point. And also check the new working of the Undo (mechanism). Undo so far is OK. But when you have "New Focus" and "Move Focus" , these actions can also be ... it is possible to undo them.

Evaluator: (constructs the chord while the observer were explaining what was being requested) OK. See if I see. (playing the first constructed chord, and clicking "New" while the chord was being played)

`Observer`: (explaining why the system did not recognised immediately the "New" click') This is a software synthesis process.

Evaluator: All right. (reading the chord analysis on screen) A sequence I, V, I, ...(incomprehensible). (reading the chord analysis on screen) Chord I, open position, root in the soprano. So, asks the chord V, the one you want now.

The experiment was interrupted for 37 seconds (from 65 to 102s), just after the insertion of the first note for the second chord at 63s, because there was an external interference (the evaluator's son entered the room and got excited about the laptop) that demanded actions from the evaluator (the removal of the child from the room) within this period.

`Observer`: (after resuming the task) OK. You are in the chord V. You are constructing the chord V.

Evaluator: OK. (after inserting the wrong note at 106s) Ops. (after deleting the wrong note and inserting the other notes of the chord) Hm, hm. Let me see. (press "Play")

`Observer`: (after listening to the I – V partial sequence) Lovely.

Evaluator: Ah, ah. Move (click the "Move" button at 130s).

`Observer`: So now you can select the chord...

Evaluator: Establish a new focus. OK

`Observer`: (while the evaluator is selecting the first chord of the sequence) Yes. And this action...

Evaluator: (after pressing the "Play" button) That means that I can actually alter the notes here (the first chord of the sequence)?

`Observer`: Yes, using the mechanisms provided.

Evaluator: (after pressing the "Next" button at 153s, that moved the focus to the second chord) OK.

`Observer`: (after a period without actions from the evaluator) When you finish the construction and press the "New" button you move to following chord on the right.

Evaluator: (coughs because of his cold)

`Observer`: Oh, gosh. (after a period without actions from the evaluator) Just one thing. Try to Undo at this point, without doing nothing.

Evaluator: (Presses the "Undo" button at 190s)

`Observer`: (after the focus is moved to the first chord) Do you know what I mean?

Evaluator: Yes. It goes back.

`Observer`: We move to the last action in the queue, that...

Evaluator: OK.

`Observer`: That was exactly the "New' that you've clicked previously.

Evaluator: Yeah. So there's a...

`Observer`: Because the "Move" has the same behaviour...

Evaluator: (after inserting the third note of the third chord at 229s, he coughs for 7s, starting at 231s)

`Observer`: Bless you.

Evaluator: Thank you. (after inserting the last note and playing the sequence) Yes. OK

`Observer`: If you like we can move to the next exercise that deals with last sequence of this study. But to press the "Next Exercise" (button) you need to first analyse the last chord pressing the "New Focus".
Evaluator: We have to press the "New Focus" even after the last chord?
`Observer`: Yeah. Because when (how) is the software able to perceive when you are happy with the chord? You need to...
Evaluator: (after pressing the "New Focus" button) OK.
`Observer`: So, you are moving to the next one, but the last one. You receive the feedback and after that you have this information.
Evaluator: (after pressing the "Next Exercise" button) Very good.

Task 4

Evaluator: (reading the instructions on screen) Construct the sequence of chords shown. OK. (evaluator inserts the four notes, plays the chord, constructs the second chord). Hm, Hm. According to the pressuposals of Schoenberg, we have to keep the voices on the same thingy.
`Observer`: That's it.
Evaluator: (plays the two chord sequence) Hm, hm. (after pressing the "New" button before the sound synthesis process finishes) Ops. New. (after inserting a wrong note for the third chord at 59s) No. (evaluator corrects the note, adds the other three notes for the third chord, and plays the sequence at 69s).
Evaluator: (after pressing the "New" button before the sound synthesis process is finished, and moving to the fourth chord) Ops. New. (after inserting the wrong note – B_2) Op, no. (after finishing the construction of the fourth chord at 89s) Hm, Hm.
`Observer`: OK. Before using the "New" (button), you can use the "Move" once or twice just to alter any of the chords.
Evaluator: (after clicking the "Move" button, and selecting the second chord) Ah!
`Observer`: To put a proper one. You can delete and insert notes accordingly. To just change the formation of the chord, keeping the same idea of close and open, because we are not checking the horizontal coherence of the sequence, if you like. We are not following properly the (horizontal) rules. I would like to ask you just to use the connecting rules,...
Evaluator: OK.
`Observer`: But I am not checking (the horizontal rules) , so if you change any of the elements there is no problem.
Evaluator: OK.
`Observer`: That's it.
Evaluator: (after changing the top note of the second chord for the seventh degree of it, and playing the sequence three times) Lovely seventh, Lovely ninth.

Unfortunately...
`Observer`: .. you are stuck at this because we are asking for a third degree chord based on a minor triad, without alterations, unfortunately.
Evaluator: (after returning the top note to the second chord at 199s) So, then you can move. (clicks on the "Move" button and selects the first chord)
`Observer`: You can move. Or you can "New" to move to the right as well.
Evaluator: (tries to modify the chord starting at 207s)
`Observer`: (noticing that the evaluator was having difficulty in changing the notes of the chord) Two notes per stave...
Evaluator: Really? All right. (continues to modify the chord up to 235s, plays the sequence, press the "Next" button and selects the third chord)
`Observer`: If you are happy, (incomprehensible) anymore.
Evaluator: (modifies the tenor note of the third chord, plays the sequence) OK.
`Observer`: To finish you need to "Move" to the last chord.
Evaluator: (press the 'New" button at 297s and the system rejects the chord)
`Observer`: Yeah. But the chord is not well formed.
Evaluator: Ah.
`Observer`: You have two B's. You are doubling the third.
Evaluator: Yeah. OK, then. (modifies the chord)
`Observer`: That's it.
Evaluator: I'll just ...
`Observer`: New twice perhaps will make it.
Evaluator: (press the "New" button, moving to the last chord of the sequence, press the "Play" button, and press the "New" button, finishing the last task).
`Observer`: We can move to the interview bit, if you don't mind.
Evaluator: I don't mind

2 Questions (Semi-structured Interview)

1. `Observer`: How easy did you find using the left button of the mouse to insert notes in chords?
   Evaluator: Very easy.
   `Observer`: Might the answer be different for users in the target group, I mean, very beginners in the learning of harmony?
   Evaluator: I don't think so. It's quite obvious. If you want to put a note you press one (button of the mouse) and if you want to take out (a note) you press the other (button of the mouse).

2. `Observer`: OK. We have a similar question. How easy did you find using the right button of the mouse to delete notes in chords?
   Evaluator: Just as easy, just as equal.
   `Observer`: Very easy?
   Evaluator: Yeah.

`Observer`: And for the target group?
Evaluator: Yes.
`Observer`: It is the same, very easy.

3. `Observer`: Did you use the "Undo" button to delete an inserted note?
Evaluator: Did I use the "Undo" button to delete or insert a note? No, I didn't[1]. I actually prefer doing by mouse buttons.
`Observer`: Did you understand how the "Undo" button works?
Evaluator: Yes. It reverses your last action.
`Observer`: That's it. Might the answer be different for users in the target group, I mean, the use of the "Undo" button?
Evaluator: Possibly. It could take a while to understand how the "Undo" (button) works but once you get used to it it is pretty clear.
`Observer`: I see.

4. `Observer`: Did you use the "Undo" button to insert a deleted note? That's even a more obscure option that is included in the ....
Evaluator: I did but I wouldn't (use the "Undo" button). I did for an experimental purpose but I wouldn't use it normally.
`Observer`: So I presume you prefer to delete using the right button of the mouse.
Evaluator: Yes, I think delete and,...
`Observer`: Sorry, to insert using the ...
Evaluator: Yes, to insert using the left button.
`Observer`: The left button to insert. About the target group, might the answer be different?
Evaluator: I think no. I think that generally people would prefer to use the mouse buttons, because it's quite quick to think with your fingers (...), you know, just input and delete and it's going to be, you know, easier just to move the arrow to the note you want to delete and just press the delete rather than using the Undo button. You might not have put that note in the last action so you might be deleting actions you don't want to delete rather than just (deleting) that note.

5. `Observer`: The "New Focus" button moved the focus to the chord immediately to the right of the current one. How easy did you find this to use?
Evaluator: It was a bit constrictive, I have to say, because I expected the software to detect the chord automatically. Once you put the chord and have to press the "New" focus in order to the software processes the chord

[1] In fact the evaluator experimented the undo button not only to delete an inserted note but also to insert a deleted note, but only in tasks 1 and 2.

and understands it and move to the next one. But once I understood that the software needed that, that was easy.
`Observer:` OK. So, easy.
Evaluator: It was easy, yeah.
`Observer:` Did you always note the feedback given?
Evaluator: Oh, yes. Oh, yes. It was very accurate.
`Observer:` Are there any other alternative ways to move to the right to the chord, immediately to the right, performing the same action as the "New" focus, for instance?
Evaluator: If you wanna move to the chord to the right, but not using the "New" focus.
`Observer:` Yeah.
Evaluator: You can press "Play".
`Observer:` Play in fact does not move. You can move to the right when you are before in a sequence already worked, using the "Move" focus, for instance. But if you are constructing a sequence and intends to move right from the current one, there is no alternative ways to move to the right.

6. `Observer:` Regarding the "Move Focus" (button), did you use it to move the focus backward(s) in the sequence to chords?
Evaluator: Yes.
`Observer:` Having moved backwards, how easy was to change notes?
Evaluator: Very easy.
`Observer:` How did you move forwards again after changing things?
Evaluator: I just pressed "New" Focus.

7. `Observer:` Did you use the Play button?
Evaluator: I did.
`Observer:` Yes. Did you find it useful?
Evaluator: Very useful.
`Observer:` Why?
Evaluator: Because it is always very important to listen to what you are writing.
`Observer:` OK. Regarding this particular button, have you got any comments, problems or suggestions for improvements?
Evaluator: Hm, no. Apart from that the system could be a little bit faster when you play it[2]. `Observer:` I see. Hm, hm.
Evaluator: But might be a ...
`Observer:` A bit of problem...

[2]Evaluator C used the system on a notebook running Linux, where the software sound synthesis program was a bit slower than the system on a Sun Ultra 5 workstation used for evaluators A and B.

Evaluator: a bit of problem of the system has been performed. Once you played (reproduces the sound – bein) I think the system should jump right back to the, you know, to your options. So, you could actually play, and play again, if you play even after the sample (that) is being played it starts again.
`Observer`: That is a limitation of this particular platform. On Unix stations the delay is about half, I could say, something like that. So, there is no time to annoy you. (incomprehensible). I agree with you that it is a little bit slow.

8. `Observer`: After completing a task, what would you expect to happen?
Evaluator: Some feedback from the tutor, from the tutor computer.
`Observer`: So, a feedback about the exercise as a whole?
Evaluator: Yes. Saying if I've used closed chord position or open chord position and how the voices moved, and if there was any unwanted parallel fifths, parallel octaves, and (incomprehensible).
`Observer`: So, we cannot put so many words in this kind of comment, otherwise it would be a little be disturbing for the student if you try to point out all the mistakes he commited, and some times some mistakes are a consequence of the other ones, so I'm wondering how to write a proper feedback, but I'm working in it, and I will ask you later, some time.

9. Any other comments, problems or suggestions for improvements?
Evaluator: I felt that if it was possible, it might be also related to the platform you are running the program, when you insert a button (note) and hold it if the note could be run around the stave, like in a gliss, (makes the sound of an ascending followed by a descending glissando) and you can hear it. If the "Play" could somehow be connected to the action of inserting a note then you can actually listen to the pitch when you are actually inserting it. I would have liked it a lot because it means that you can actually not only, you don't have to be on a particular point of the stave but you actually can bring it up close to the pitch and then you can actually hear it. Possibly a small window showing which note you are inserting in a stave, like, you know, F sharp, blah , blah, blah.
`Observer`: I see. That's a different action that I was not planning exactly, but I know what you mean, it would be a very interesting thing. Another suggestion that (I) was given was that to only change the cursor (shape) when you are on a line or on a space. This would be helpful as well.
Evaluator: Hm, hm. OK. Oh, I see. Change the cursor shape.
`Observer`: Yeah. You know that when the cursor has a particular format (shape) it will be on a line or on a space. And probably this will be pretty use to do, and I will think about these suggestions about playing. I know

several packages that do this action like Cakewalk when you drag a note...
Evaluator: You can actually hear it.
`Observer:` ...the effect of moving it.
`Observer:` And this software synthesis process is a little bit tricky perhaps for this particular thing (you are suggesting). I'll take into account your comments in the future versions, and I'll let you know which of your comments were really implemented in the future platforms. I would like now to thank you for the participation in this study.
Evaluator: Thank you. `Observer:` Thanks very much.

Appendix B

Summative Evaluation Data

This appendix contains the materials used in the evaluation of the learning environment (Chapter 8). It also includes full transcriptions of the semi-structured interviews conducted with the evaluators before and after interaction with the environment.

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HANDOUT FOR THE EMPIRICAL STUDY ON

A Harmony Learning Environment

Márcio Brandão*

Description

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The study consists of four stages. In the first stage some basic background information is requested from you. The second stage involves you acquiring some familiarity with the environment mechanisms and the way it presents exercises and feedback. In the third stage exercises are presented in a similar sequencing as in Schoenberg's book, and you are asked to try to solve them correctly. Finally, the last stage of this study consists of a semi structured interview intended to collect your overall impression of the environment.

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1 Theoretical Background

1.1 The Diatonic Triads

The chords involved in this study are based on the basic triads of the C-major diatonic scale shown in Figure 1. Note the use of capital and lowercase numerals to indicate the chord type:

- capital Roman numerals represent a major chord;
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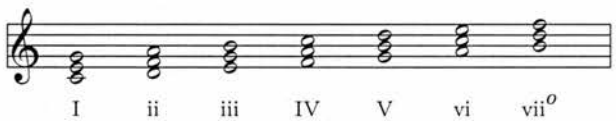

Figure 1: The diatonic triads in C-major

1.2 Chord Construction

The constructions of chord is based on the four-part writing, which involve the assignment of notes to the soprano, tenor, alto and bass voices. Chords must present the three triad tones and a doubling tone (but not a repetition of a pitch), restricted to the root degree for this study. The following *position* of chords must be considered:

close when no other chord tone can be inserted between two adjacent voices of the upper three voices; or

open when one and only one chord tone can be inserted between any two adjacent voices of the upper three voices.

- Chord construction questions:

  1. Which tone goes in the bass? The root degree.[1]
  2. Which tone goes in the soprano?
  3. What is missing?

Open Position Chords Closed Position Chords

Figure 2: Examples of chord positions

[1] For the part of Schoenberg's curriculum covered in this study all chords are in root position.

1.3 Chord Connections

(a) Chords with Common Tones

The sequence of steps from Schoenberg's method to be carried out in order to achieve a "good" connection of chords is based on the *law of the shortest way*, in which common tones must be kept on the same voice, and each voice must take the smallest step which will allow the other voices to take small steps.

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2. Which are the common tones? Sustain them in the same voices;
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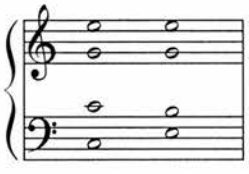

I iii

Figure 3: Example of chord connection

(b) Preparation (IV – vii^o / ii – vii^o) and resolution (vii^o – iii)

Chord connection questions:

1. Which tone goes in the bass? The root degree;
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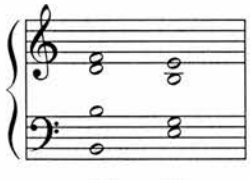
One example of a completed sequence where the above constraints were observed is shown in Figure 4.



vii^o iii

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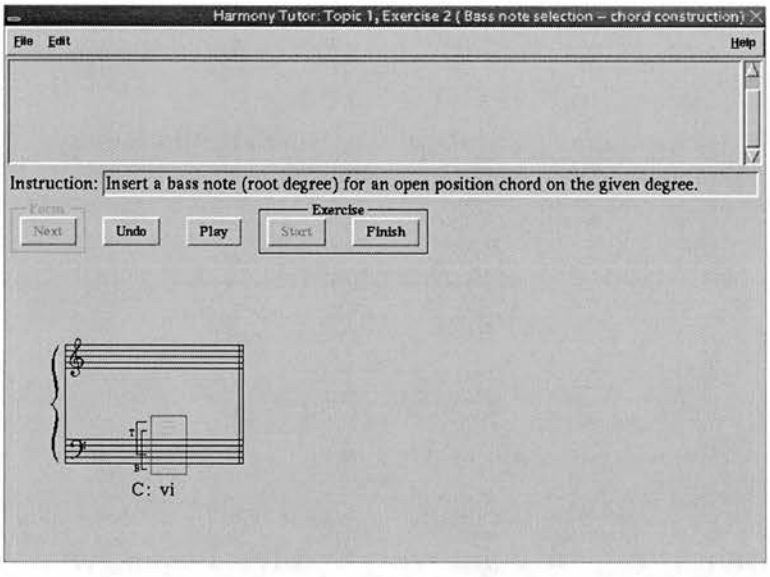

Figure 5: Environment screen

You can insert notes by means of clicking the <left> button of the mouse when the mouse cursor is within a red rectangle. Note that the cursor changes its head according to its positioning on a line or a space of the staves. The note name also appears on screen.

You can delete previously inserted notes by means of clicking the <right> button of the mouse on them. The <Undo> button removes the effect of your last action on the environment.

After completing an exercise, you must press the <Finish< button, and you will receive some feedback about the correctness of your solution or otherwise. Simultaneously, all rectangles become blue to indicate that the exercise is finished.

Some exercises involve the construction of sequences of two or more chords. The <Next> button must be used, after a chord is completed, to move to the chord immediately to the right. However, this movement will take place only when the current chord and the connection to the previous one (the one immediately to the left) is correct.

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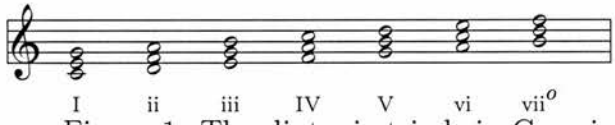

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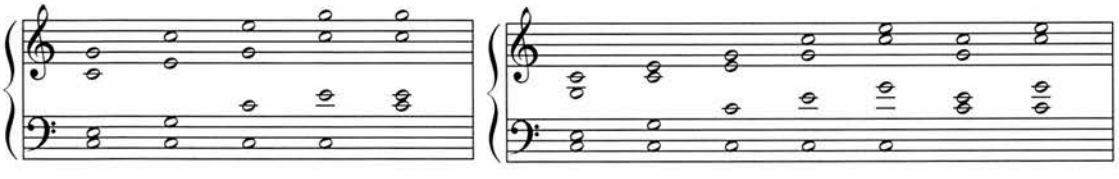

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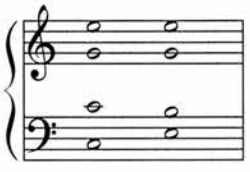

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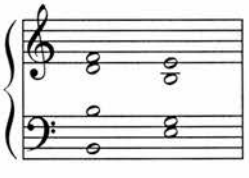

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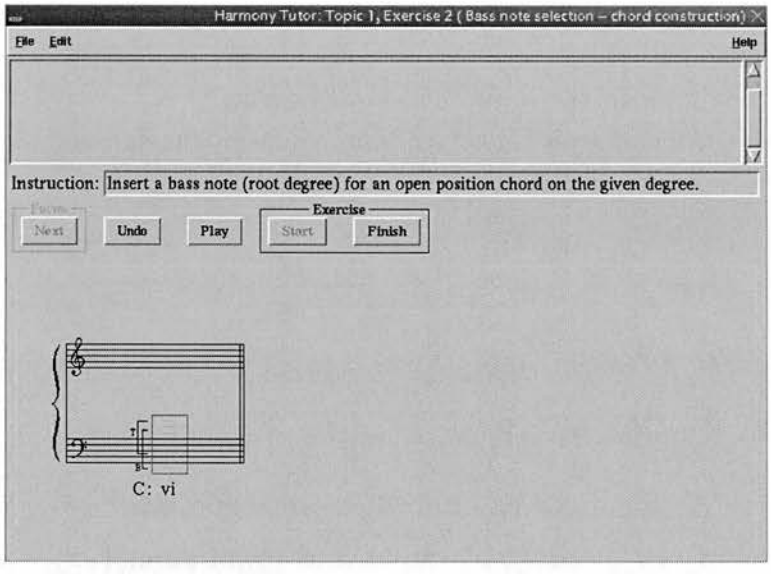

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EXERCISES FOR THE EMPIRICAL STUDY ON

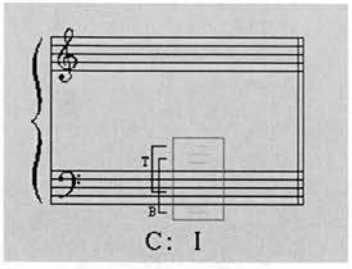
A Harmony Learning Environment

Description

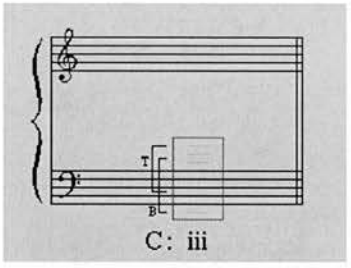
This document describes the designed exercises that were used on the evaluation study on the harmony learning environment, organised by topics.

Topic 1 – Selecting the Bass Voice

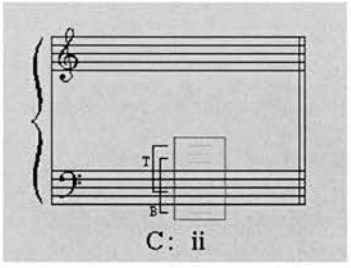
Topic 1 aimed to help evaluators to get used to the note insertion and deletion mechanisms, and at the same time to introduce Schoenberg's first step for chord construction: to select the bass note. Figure 1 shows the exercises, on which evaluators are asked to "insert a bass note (root degree) for a chord on the given degree".



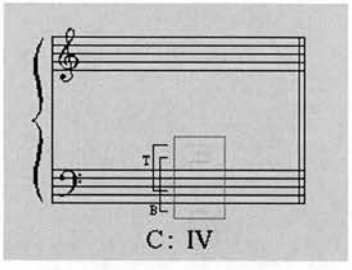
(a) First degree



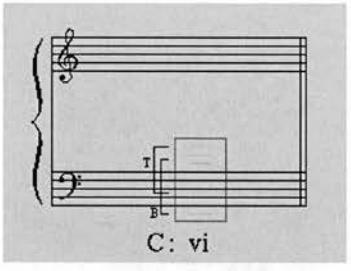
(b) Third degree



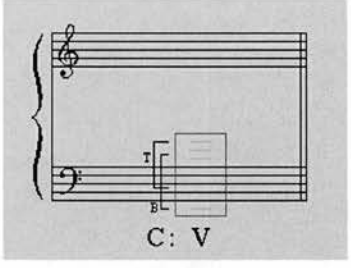
(c) Second degree



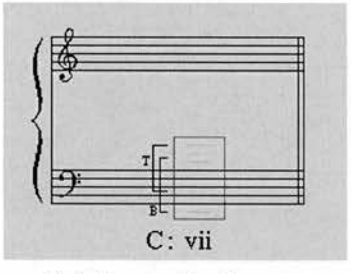
(d) Fourth degree



(e) Sixth degree



(f) Fifth degree

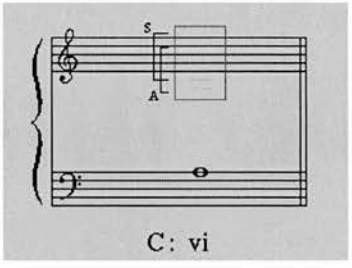


(g) Seventh degree

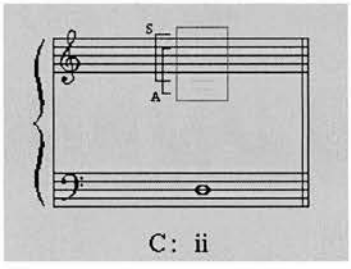
Figure 1: Topic 1 (bass note selection) exercises

Topic 2 – Selecting the Soprano Voice

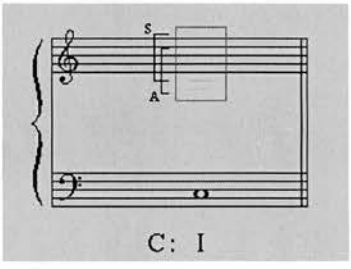
Figure 2 shows the exercises for Topic 2, in which evaluators are asked to "insert a bass note (root degree) for a chord on the given degree".



(a) Close position chord



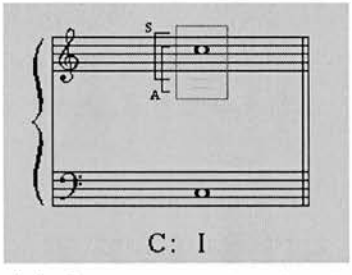
(b) Open position chord



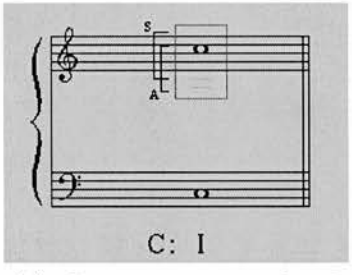
(c) Close position chord

Figure 2: Topic 2 exercises

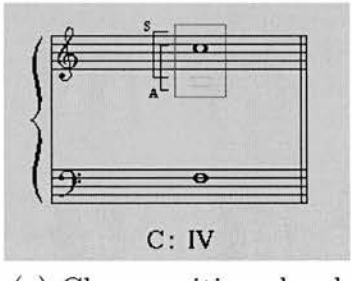
Topic 3 – Selecting the Alto Voice



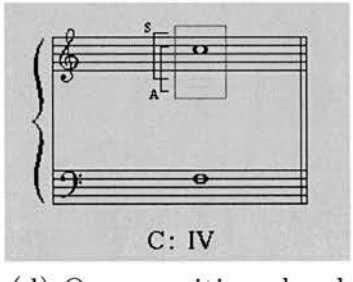
(a) Close position chord



(b) Open position chord



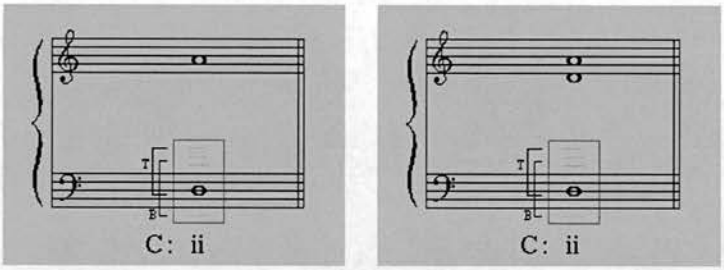
(c) Close position chord



(d) Open position chord

Figure 3: Topic 3 (alto note selection) exercises

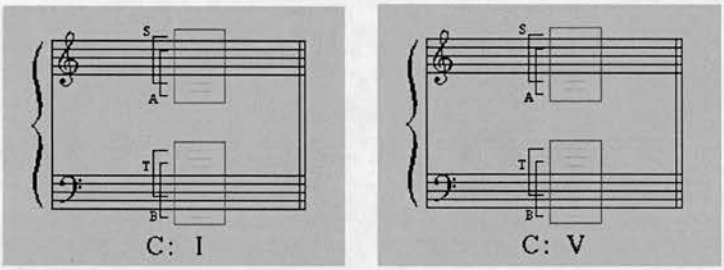
Topic 4 – Selecting the Tenor Voice



(a) Close position chord (b) Open position chord

Figure 4: Topic 4 (tenor note selection) exercises

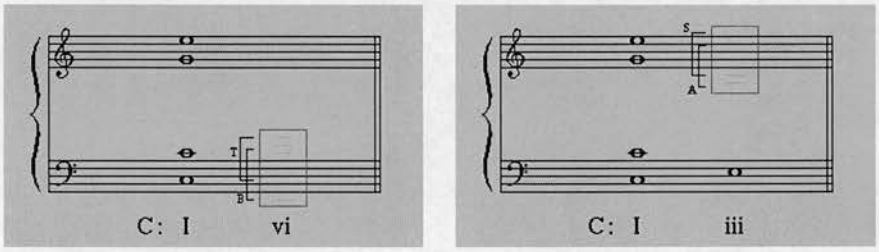
Topic 5 and 6 – Constructing Chords



(a) Close position chord (b) Open position chord

Figure 5: Topics 5 and 6 (chord construction)

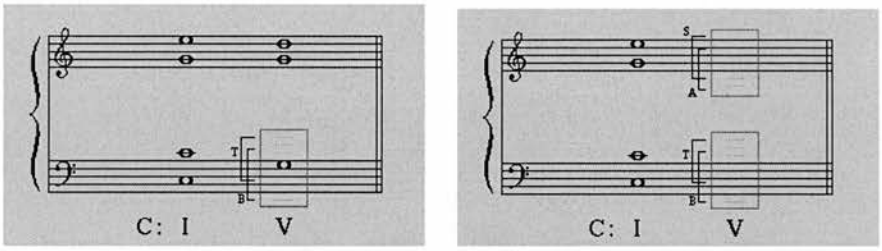
Topic 7 and 8 – Connecting Chords



(a) Bass note selection (b) Alto note selection

Figure 6: Topics 7 and 8 (chord connection

Topic 9 and 10 – Constructing Chords



(a) Tenor note selection (b) All voices note selection

Figure 7: Topics 9 and 10 (chord connection)

Topic 11 – Discovery Mode (2 chords)

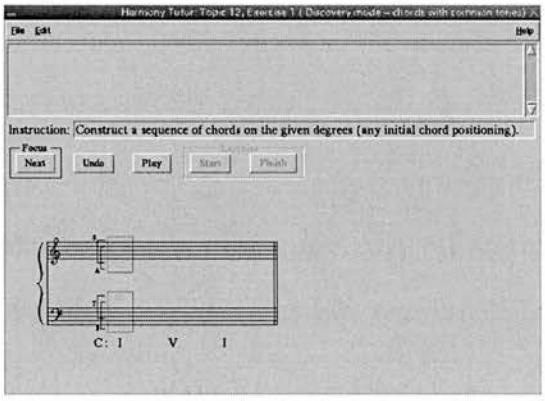


Figure 8: Topic 11 (discovery mode – connection of chords with common tones)

Topic 12 – Discovery Mode (3 chords)

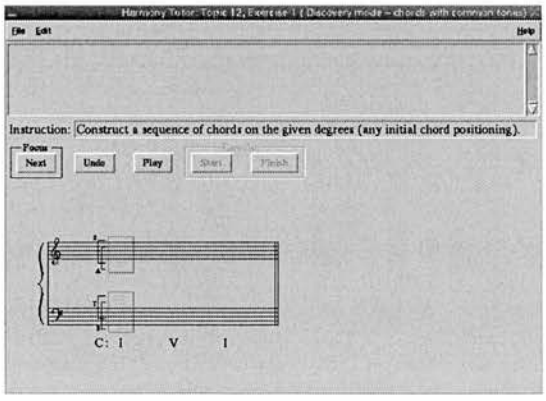


Figure 9: Topic 12 (discovery mode – chords with common tones)

Topic 13.1 – Discovery Mode (4 chords)

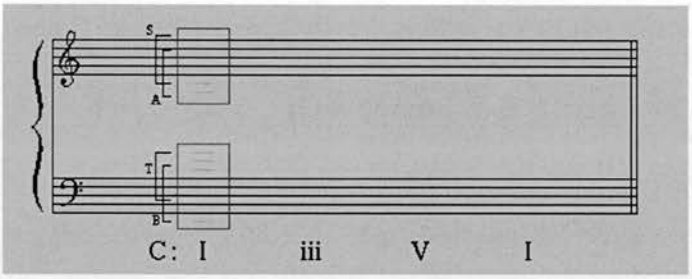


Figure 10: Topic 13, exercise 1 (discovery mode – chords with common tones)

Topic 13.2 – Discovery Mode (4 chords)

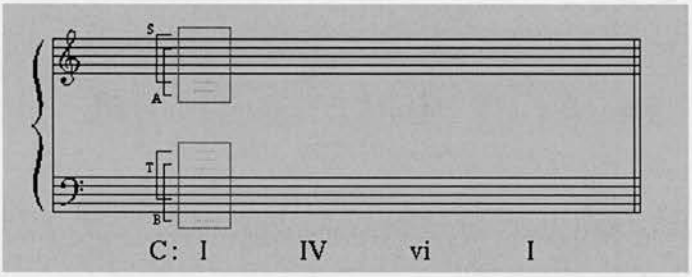


Figure 11: Topic 13, exercise 2 (discovery mode – chords with common tones)

Topic 13.3 – Discovery Mode (5 chords)

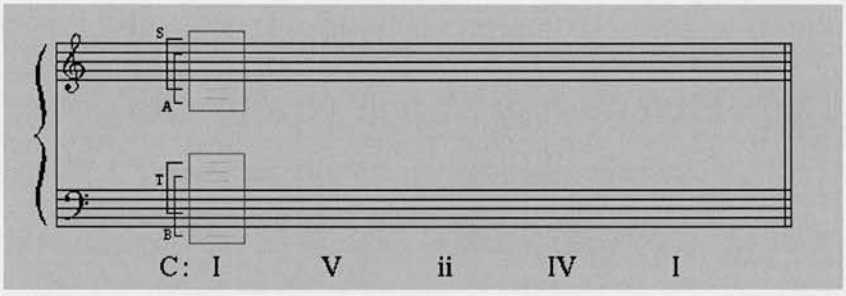


Figure 12: Topic 13, exercise 3 (discovery mode – chords with common tones)

Topic 13.4 – Discovery Mode (6 chords)

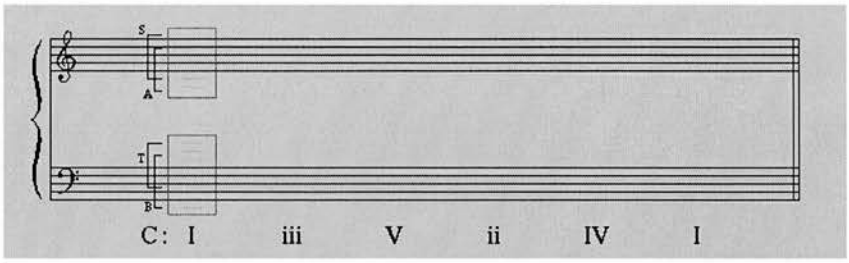


Figure 13: Topic 13, exercise 4 (discovery mode – chords with common tones)

Topic 13.5 – Discovery Mode (6 chords)

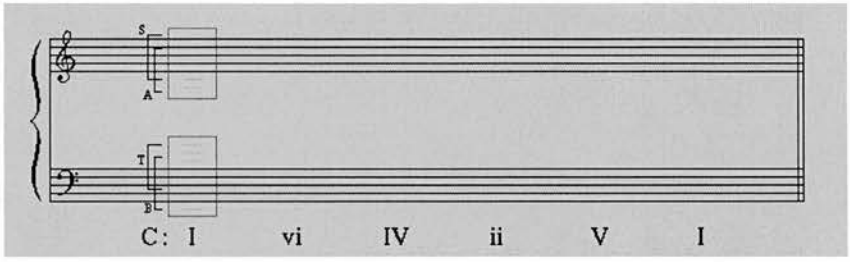


Figure 14: Topic 13, exercise 5 (discovery mode – chords with common tones)

Topic 14.1 – Discovery Mode (with viith chord)

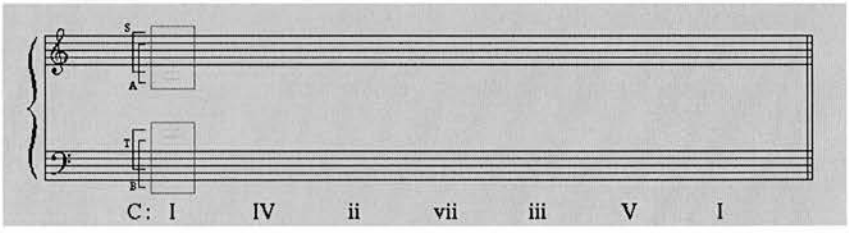


Figure 15: Topic 14, exercise 1 (discovery mode – chords with common tones + 7^th degree)

Topic 14.2 – Discovery Mode (with viith chord)

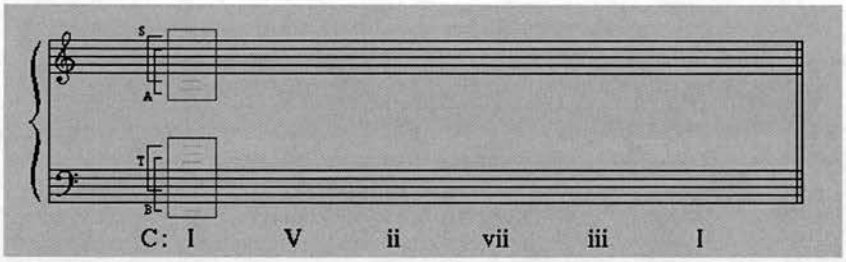


Figure 16: Topic 14, exercise 2 (discovery mode – chords with common tones + 7^th degree)

Semi-structured Interview Sheet for the Empirical Study on

A Harmony Teaching Environment Interface

Participant: _____

1 Basic Information

1. Describe your background in music.
2. Have you taught harmony courses? For students in which year?
3. What was the main textbook?
4. On a scale of 1 to 7, where 1 is not important at all and 7 is very important, how important is the harmonisation of melodies for the global assessment of first year harmony students?
5. On a scale of 1 to 7, where 1 is not important at all and 7 is very important, how important is the harmonic analysis of musical pieces from the eighteenth and nineteenth centuries to the harmony teaching?
6. Have you used Schoenberg's "Theory of Harmony" in your teaching? In which context?
7. Do you think it is feasible to run an undergraduate course on harmony centred around this book? Please explain your answer.

2 Questions (Semi-structured Interview)

1. Do you think that the music notation interface of the environment is appropriate for the method?

2. On a scale of 1 to 7, where 1 is very difficult and 7 is very easy, how easy did you find using the mouse to insert and delete notes?
   Might the answer be different for users in the target group (beginners)?

3. On a scale of 1 to 7, where 1 is very difficult and 7 is very easy, how easy did you find using the interface buttons to complete exercises?
   Might the answer be different for users in the target group?

4. On a scale of 1 to 7, where 1 is not meaningful at all and 7 is very meaningful, how meaningful was the feedback given at the end of exercises?
   Might the answer be different for users in the target group?

5. On a scale of 1 to 7, where 1 is not helpful at all and 7 is very helpful, how helpful was the feedback provided for correcting later exercises in the same topic?
   Might the answer be different for users in the target group?

6. On a scale of 1 to 7, where 1 is not consistent at all and 7 is very consistent, how consistent was the environment's sequencing of exercises to the one in Schoenberg's method?

7. Is the <Next> button representing in an intuitive way Schoenberg's left-to-right pedagogical constraint?

8. On a scale of 1 to 7, where 1 is not consistent at all and 7 is very consistent, how consistent was the environment and its graphical interface to the pedagogical constraints of the method?

9. On a scale of 1 to 7, where 1 is not beneficial at all and 7 is very beneficial, how beneficial was to learning the design decision of taking away from students the responsibility of choosing the chord sequence to work with[1]?

10. On a scale of 1 to 7, where 1 is not appropriate at all and 7 is very appropriate, how appropriate is the control of the student's behaviour?

11. Is it better to leave students responsible for getting aural feedback (from a musical instrument) rather than having it readily available as in the prototype?

[1] This decision was made taking into account the fact that this might be a distracting element to beginners. Also, the didactic control of the user's actions in this case can be more precise.

12. Is the capability of having immediate aural feedback beneficial to learning?
13. Is Schoenberg's exploration of solutions properly embodied in the prototype?
14. Is it better to leave students responsible for assessing their exercises by themselves, as suggested in Schoenberg's method, rather then receiving didactic feedback after each chord construction?

Semi-structured Interview Sheet for the Empirical Study on

A Harmony Teaching Environment Interface

Evaluator A: John Kitchen

1 Basic Information

1. `Observer`: Describe your background in music.
   Evaluator: My background in Music? Erm... Well, I first started playing piano, age 5, and it was very interesting, 'cause we were talking about harmony, and one of the things which interested me from an early age was harmony. And I used to play hymn tunes all the time....
   `Observer`: Hm, hm.
   Evaluator: ...endlessly, and looking at... I didn't know that at that time that was the harmonies that interested me.
   `Observer`: So, you were young.
   Evaluator: I was five.
   `Observer`: Five, OK.
   Evaluator: And (incomprehensible) harmony then. So... That... Then we went on from there. I had piano lessons and...
   `Observer`: And so on.
   Evaluator: And so on.
   `Observer`: OK.

2. `Observer`: Have you taught harmony courses? *Evaluator:* Yes. I've taught harmony really since I started teaching in St. Andrews University in 1976. I've taught harmony for a very long time.
   `Observer`: I see. So, and for students in which year in harmony?
   Evaluator: Well, erm... here (University of Edinburgh) in all years. I've taught... Well, actually not so much first year. No teaching (for) first year. I've taught second year and then advanced harmony, third and fourth year... years. `Observer`: OK.

3. `Observer`: What was the main textbook?

Evaluator: Well, there wasn't one (laughs). We are tending to teach at the... We haven't used a textbook as such. Erm... What we have used, I mean, for example, in teaching Bach chorales we obviously use the Riemenschneider collection But we've often made our own sheets and things, and that what I've done sometimes with information. And then have a look at particular composer's works. But I've never used one particular textbook. There is the Anna Butterworth textbook on harmony that I have and I refer to, but I haven't used it systematically.
`Observer`: OK. So, you develop your own material.
Evaluator: Really. Yes, yes. That's what it amounts to. Yeah.

4. `Observer`: On a scale of 1 to 7, where 1 is not important at all and 7 is very important, how important is the harmonisation of melodies for the global assessment of first year harmony students?
Evaluator: Very important. I suppose that' 7.
`Observer`: 7.
Evaluator: I think so, anyway.
`Observer`: OK (laughs).

5. `Observer`: On the very same scale, where 1 is not important at all and 7 is very important, how important is the harmonic analysis of musical pieces from the eighteenth and nineteenth centuries to the harmony teaching?
Evaluator: I can... I think is very important. I think... It would have to be 7.
`Observer`: OK.

6. `Observer`: Have you used Schoenberg's "Theory of Harmony" in your teaching? In which context?
Evaluator: No, I haven't (laughs).
`Observer`: OK (laughs).
Evaluator: Sorry (laughs).

7. `Observer`: Do you think it is feasible to run an undergraduate course on harmony centred around this book?
Evaluator: Well, erm... Having, as I said to you, read parts of it, and I think that what he says is, erm..., is all..., I agree with it all, is very good. I would... I think that students would find slightly, erm..., well, as I said, it takes a very long time to see things which I think are quite simple.
`Observer`: Hm, hm.
Evaluator: Erm... I'm not saying... So, the answer to your question isn't necessarily no, but I think it is a bit wordy, there are too many words. There are some musical examples but, I mean, I would have thought teaching

harmony would benefit from, I mean, yes, he has some examples like this (shows a musical example in Schoenberg's "Theory of Harmony" book).
`Observer`: But not from the (musical) literature, I mean.
Evaluator: But, yeah.
`Observer`: It's not melodic example(s) as in most harmony courses.
Evaluator: Yeah, yeah. I think there are too many words.
`Observer`: Hm, hm. If this contents, the basic contents were extracted...
Evaluator: Yes.
`Observer`: ...do you think it would be feasible?
Evaluator: I think... The basic contents are good. I think... Interesting... I don't know who has underlined these (points to the copy of parts of Schoenberg's book that was provided to the evaluators in advance), are they yours?
`Observer`: Yes.
Evaluator: Well, the bits that are underlined are in fact the important bits, nearly all. and I think you can extract those and find something that's, erm... very good, but I think that if you gave students this to read, certainly first year students, they would glaze over. I think there are too many words.
`Observer`: I agree.
Evaluator: (laughs)
`Observer`: And at the preface of his book (Schoenberg's "Theory of Harmony") you can read that one of his disciples..., disciples..., he extracted this contents and publish a book (with it) but Schoenberg did not quite authorise it.
Evaluator: Yes. I see.
`Observer`: But I had no access to this book...
Evaluator: Hm, hm.
`Observer`: ...and there are just a few volumes mainly in these Schoenberg's museums, and...
Evaluator: Yes, I see. Yeah.
`Observer`: So, erm..., I think that's the basic information I would like to collect from you, and we can start interacting with the interface...
Evaluator: OK.
`Observer`: ...but before I would ask you to take a look at this material (gives to the evaluator the handout) it's a summary of the summary (laughs).
Evaluator: A summary of the summary, yeah. OK. Yes, please.

2 Questions (Semi-structured Interview)

1. `Observer`: Do you think that the music notation interface of the environment is appropriate for the method?
   Evaluator: Yes, yes. Yes, I do.
   `Observer`: OK.

2. `Observer`: On a scale of 1 to 7, where..., where 1 is very difficult and 7 is very easy, how easy did you find using the mouse to insert and delete notes?
   Evaluator: (laughs) Well...
   `Observer`: 1 to 7. 1 very difficult and 7 very easy.
   Evaluator: Somewhere in the middle. Perhaps not... I mean... That's because of me. I mean, I just do these things enough (puts the right hand of the mouse, and presses the buttons). So. I would have thought, erm..., 4 or something.
   `Observer`: 4. Might the answer be different for users in the target group, for beginners learning harmony?
   Evaluator: Yes, I'm sure it would.
   `Observer`: OK. Erm... Why?
   Evaluator: Old people like me can't (laughs)... No, I mean, I could... I would... I would find that quite easy after...
   `Observer`: You were getting used quite quickly.
   Evaluator: ...after (incomprehensible). I mean, you get used to that very quickly. I mean, there is no difficulty about it at all. I mean, because I pressed something wrong is not the fault of this (points to screen), is the fault of me. No, it's fine. It's very good.
   `Observer`: Hm, OK. Thanks.

3. `Observer`: On a scale 1 to 7, where 1 is very difficult and 7 is very easy, how easy did you find using the interface buttons to complete exercises?
   Evaluator: Very easy.
   `Observer`: Very easy.
   Evaluator: Whatever that is. 7.
   `Observer`: 7.
   Evaluator: Say, call it 7.
   `Observer`: Very easy. OK.
   Evaluator: It is very easy. Yeah.

4. `Observer`: So, now 1 is not meaningful at all and 7 is very meaningful. How meaningful was the feedback given..., given, in general?
   Evaluator: Ah... I think is OK. Oh... 6.
   `Observer`: Hm, hm. OK.

5. `Observer:` Now 1 is ve... is not helpful at all and 7 is very helpful. How helpful was the feedback provided for correcting later exercises in the same topic?
   Evaluator: Ahm... Apart from the bit that told me the wrong thing...
   `Observer:` (laughs).
   Evaluator: Ahm, I suppose... Yes, it's... I think it's pretty help... Say 6 again.
   `Observer:` Might the answer be different for users in the target group?
   Evaluator: Probably, yes. Is...
   `Observer:` A higher score or a lower score?
   Evaluator: A higher score.
   `Observer:` Ah, OK.
   Evaluator: They would probably say 7. I think...
   `Observer:` (it's) more useful to them.
   Evaluator: Yeah. I think so. The... problem when you know the thing from another, you know, when is something that is done for a long time, you... I'm not really following steps.
   `Observer:` You're skipping steps.
   Evaluator: I'm skipping steps. Which then leads to problems. You skip steps and then you, ahn...
   `Observer:` Yeah, that's experience.
   Evaluator: Yes. It does always (incomprehensible) .

6. `Observer:` OK. Now 1 is not consistent at all and 7 is very consistent. How consistent was the environment's sequencing of exercises to the one in Schoenberg's method?
   Evaluator: It seem very consistent. So, that's 7.
   `Observer:` OK.

7. `Observer:` Is the <New> button representing, erh... Sorry. Is the <New> button representing in a natural way Schoenberg's left-to-right pedagogical constraint? The point is that, another subject that was trying to use it (points to the environment), he asked: Oh, how could I put the bass (follows the constructed bass line on screen with the finger) and then putting the notes? This is against Schoenberg ('s method). Schoenberg states that you need first to build a chord...
   Evaluator: Yes.
   `Observer:`...and then following one, not as you usually are used to do.
   Evaluator: Yes.
   `Observer:` That's the point I am trying to address in here.
   Evaluator: I see.
   `Observer:` Is this (pointing to the <Next> button on screen) <New>

button... Sorry, is not <New>. Is <Next> (laughs).
Evaluator: <Next>.
`Observer:` Yeah. Is this <Next> button representing this pedagogical constraint, this left-to-right pedagogical constraint?
Evaluator: I think so. I mean, I... I was tending to try and see the whole sequence because I think is important to, you know, when you are teaching harmony, to see always from one chord to the next. And I think, erm... Yeah, I mean. I think that, that was OK. So, I mean, 7.
`Observer:` OK (laughs).
Evaluator: I couldn't think of a better way.
`Observer:` Hm, hm.

8. `Observer:` The same scale. 1 is not consistent at all and 7 is very consistent How consistent was the environment and a graphical interface to the const... , to the general pedagogical constraints of the method? So, in addition to this left-to-right (constraint), this... trying to impose this sequencing of bass, and then the soprano, and then what is missing, as in the beginning of the...?
Evaluator: I think it was very consistent. Yeah.
`Observer:` 7.
Evaluator: 7. Yes.

9. `Observer:` 1 is not beneficial at all and 7 is very beneficial. How beneficial was to learning the design decision of taking away from students responsibility of choosing the chord sequence to work with? I mean that: the st.. Schoenberg advises the students to write the sequence and then (to) start to work with it. We are imposing the Roman numeral sequence...
Evaluator: Yes.
`Observer:` and..., so...,
Evaluator: Yes.
`Observer:` instead of leaving to the students this decision of what to work with.
Evaluator: Hm, hm. So...
`Observer:` The question...
Evaluator: ...the question...
`Observer:` is: How beneficial was to learning the design decision of taking away from students this decision?
Evaluator: I think that for a beginner you have to do this. Erm... So, I am not quite sure on how to answer this.
`Observer:` I see (laughs).
Evaluator: Erm... Erm...
`Observer:` You would not like to give grades (laughs). (do) You think is

convenient, somehow, for beginners...
Evaluator: I think that for beginners you have to do this. You have to take away that decision from them, and impose... So, I suppose, it's... is beneficial.
`Observer`: Something in the middle?
Evaluator: I think we would have to do that. So, I mean, 6.
`Observer`: 6.

10. `Observer`: 1 is not appropriate at all and 7 is very appropriate. How appropriate is the control of the student's behaviour?
Evaluator: What do you mean? Erm...
`Observer`: So, we are erm... imposing somehow the sequencing of topics like...
Evaluator: Yes.
`Observer`: ...first the bass...
Evaluator: Yes. Yeah.
`Observer`: ... and after that you ask for him to put the soprano...
Evaluator: Yeah.
`Observer`: ...and to fill the gaps. And after that the next chord, and etcetera et al.
Evaluator: Hm, hm.
`Observer`: So... How appropriate, do you think, it was this kind of control of the student's behaviour.
Evaluator: I think that, that again for a beginner it's appropriate. I mean, I was not doing it.
`Observer`: Hm, hm.
Evaluator: I had the who..., you know, I was just clicking from the top to the bottom because I had the chord worked out.
`Observer`: Hm, hm.
Evaluator: I wasn't going through the steps. I was just making, you know... But, I think, erm.., again, controlling that for beginners is good. I suppose that's 7.

11. `Observer`: Is it better to leave students responsible for getting aural feedback from a musical instrument rather than having it readily availa... available as in the prototype?
Evaluator: (laughs). Yeah, well. I don't know. Erm... I think, you know, I think we have to accept that it is useful to have it available, readily available here (points to the <Play> button with the mouse), erm..., you know. I think we have to... It's just that I've never been used to that. But, erm... Yes. It's, It's... Students (would) do find that useful.
`Observer`: So...

Evaluator: I think...
`Observer:` when you are comparing it's better?
Evaluator: Yes. It is. Yeah.
`Observer:` Hm, hm.

12. `Observer:` Do you think that this capability of having immediate aural feedback beneficial to learning? I think that this question is quite similar, in fact.
Evaluator: Yes, well, I think it is. The answer is yes.
`Observer:` OK.

13. `Observer:` Is Schoenberg's exploration of solutions properly embodied in the prototype? So, Schoenberg advises for the students to explore, he says that the search is more important than anything else.
Evaluator: Yes. I think so, because, yes, it does allow you to do that. Erm... And it allows you to do that and tells you when you've... when you've gone wrong.
`Observer:` Hm, hm.
Evaluator: So, I think the answer is yes.
`Observer:` OK.
Evaluator: (laughs)

14. `Observer:` And now the last question: Is it better to leave students responsible for assessing their exercises by themselves, as suggested in Schoenberg's method, rather then receiving didactic feedback after each chord construction? So we are are comparing the student following the book (shows Schoenberg's "Theory of Harmony" book)...
Evaluator: Hm, hm.
`Observer:` ...a hypothetical student, I think (laughs)...
Evaluator: Yes, yes.
`Observer:` ...erm, and we are comparing to with this kind of feedback that he's receiving, so. In Schoenberg's method, perhaps he(the student)'s used to think that he is careful about what he's doing wrong and etc-era, and... while here (points to the environment) he receives readily the...
Evaluator: Hm, hm.
`Observer:` ...the assessment from the system.
Evaluator: Yes, yes, so...
`Observer:` Do you think it's better this situation of leaving students responsible for assessing themselves, or do you think or is it better in a prototype like that.
Evaluator: It is better like that.
`Observer:` So, prototype is better.
Evaluator: I would think so.

Semi-structured Interview Sheet for the Empirical Study on

A Harmony Teaching Environment Interface

Evaluator B: Noel O'Regan

1 Basic Information

1. `Observer`: Describe your background in music.
   Evaluator: I have a University of music degree and also a Chemistry degree. Hm. Lots of experience of singing and playing keyboard instruments and a PhD from Oxford.
   `Observer`: In Music?
   Evaluator: In Music History, sort of a bit of analysis.
   And lots of teaching experience, for several years. Is that something like that you meant? Is that enough for what you want?
   `Observer`: Oh, yes. Much more than enough.
   Evaluator: OK.
   `Observer`: But I have a couple of more questions.
   Evaluator: Hm, hm.

2. `Observer`: Have you taught harmony courses?
   Evaluator: Yes.
   `Observer`: For students in which year?
   Evaluator: Mainly for first years at Edinburgh (University), and also a bit of second year level. And in Lancaster also for first and second years.
   `Observer`: For several years?
   Evaluator: For several years. Yes.
   `Observer`: Pretty good for this study.
   Evaluator: Well, yes. I'm suppose that I'm one of the people, who are most involved, someone in Edinburgh, who are most involved And actually teaching this at this sort of level, well, something at the level of Schoenberg but we do it differently.

3. `Observer`: This leads us to the next question: What was the main textbook?

Evaluator: We don't tend to use a textbook. I tend to give handouts, and a series of exercises which form a textbook, I suppose. But I never found a single textbook appropriate to the way that has been done in Edinburgh and the way that I would do it, so. The nearest textbook which I did try to use for a bit with David Kimbell who I used to work with.
`Observer:` David Kimberley?
Evaluator: David Kimbell, who is in the Department (of Music at University of Edinburgh) was Anna Butterworth's. Do you come across that? It's Anna Butterworth, who is at Napier University.
`Observer:` Ah, Anna Butterworth. Yeah, yeah. I came across.
Evaluator: Harmony. It's a bit more... It has a lot of good points, but we didn't find it entirely useful.
`Observer:` So, you are developing your own material.
Evaluator: Yes, definitely I'm developing my own material.

4. `Observer:` OK. On a scale of 1 to 7, where 1 is not important at all and 7 is very important, how important is the harmonisation of melodies for the global assessment of first year harmony students?
   Evaluator: Right. Harmonisation of melodies. I guess it involves half of the course effectively, so it's important. I mean, within that half of the course it is essentially and it is the most important thing we ask them to do. So, depending on how you want to count that.(...)
   `Observer:` In your opinion, between 1 to 7?
   Evaluator: I mean, it's not the only thing. I would say something in the middle, I suppose. So, 3 or 4 should reflect how much we do of it.

5. `Observer:` On a same scale, where 1 is not important at all and 7 is very important, how important is the harmonic analysis of musical pieces from the eighteenth and nineteenth centuries to the harmony teaching?
   Evaluator: Erm.. Again, let's say 4. Is essentially important, I think.
   `Observer:` So, 4 in this case and the previous one 3?
   Evaluator: 3 stroke 4 (for the previous question). `Observer:` 3 stroke 4.

6. `Observer:` Have you used Schoenberg's "Theory of Harmony" in your teaching?
   Evaluator: No.
   `Observer:` No. Hm, hm.

7. `Observer:` Do you think it is feasible to run an undergraduate course on harmony centred around this book?
   Evaluator: It's feasible. It would be much slower than we do at the moment, I think.
   `Observer:` Hm, hm.

Evaluator: Feasibility we would have to look at it in terms of the sort of courses we do but reading it on your suggestion... `Observer:` Hm, hm.
Evaluator: ... for the thing it's quite interesting, but my feeling... It's also close to how I learnt harmony... `Observer:` Hm, hm.
Evaluator: ... doing chord progressions but at this stage we don't take the time to do at the moment. I think it would be part of an introductory module of some sort to, to..
`Observer:` To the real course of harmony.
Evaluator: Yes. That is probably how I would say it (incomprehensible). But we..., we..., as you probably know, we are looking at the harmony teaching anyway in Edinburgh for next year (incomprehensible). over the course address to this year, and it may well be that some aspects of that could be used.
`Observer:` Aspects of Schoenberg could be incorporated for the undergrads?
Evaluator: Of Schoenberg, yes. Of using this method of doing chord progression rather than harmonising a melody.
`Observer:` I see. Analysing a melody and from the analysis developing the individual voices.
Evaluator: Hm, hm. Yes. (Schoenberg's) is a more rigorous...
`Observer:` Methodology.
Evaluator: methodology for students that not done any (harmony) before. As you probably know, most of our students would have done some before which would make this probably a bit of a tedious exercise.
`Observer:` Hm, hm.
Evaluator: We are (incomprehensible) getting students that haven't done very much before, and something like this (method) might be useful.
`Observer:` OK. So, we can return to these points after the real interaction, but before the interaction I think it could be a good idea to take a look at the handout.
Evaluator: To see if we are talking the same language. Yeah.

2 Questions (Semi-structured Interview)

1. `Observer:` First question: Do you think that the music notation interface of the environment is appropriate for the method?
   Evaluator: Yes, yes.
   `Observer:` Hm, hm.

2. `Observer:` On a scale of 1 to 5, where 1 is very difficult and 7 is very easy, how easy did you find using the mouse to insert and delete notes?
   Evaluator: Just start again, because you put 7 ...
   `Observer:` 1 is very difficult and 7 is very easy.

Evaluator: On a scale of 1 to 7. OK. Erm... So, how easy did I find, how did I find...?
`Observer:` To use the mouse to insert and delete notes?
Evaluator: Erm... I found some more difficult, so. Erm. 1 is very difficult, you said.
`Observer:` 1 is very difficult.
Evaluator: OK. Probably 3, or something like that.
`Observer:` 3.

3. `Observer:` On a scale of 1 to 7, where 1 is very difficult again and 7 is very easy, how easy did you find using the interface buttons to complete the exercises?
Evaluator: That was very easy. That's 1 I think. Sorry. That's 7, I mean.
`Observer:` Sorry, I forgot to ask for the previous question about the insertion and deletion of notes: Might the answer be different for users in the target group? Beginners. We are talking about beginners.
Evaluator: I think it's more, it's more familiarity with the PC mouse.
`Observer:` Hm, hm.
Evaluator: I think it might be, yeah, yeah, I'm sure it will be easier.
`Observer:` Hm, hm.
Evaluator: It's just because I'm not used to a mouse that jumps around so much.
`Observer:` Oh, I see. Because of this particular model.
Evaluator: Because of this particular model. I mean, I would have thought... If I were using the mouse that I normally use I would have find much easier.
`Observer:` Wow. I'm impressed, because you were very quick in solving the exercises, in general.
Evaluator: But that's because the Mac mouse is much less jumpy on the screen.
`Observer:` So, regarding the same question: Might the answer be different for users in the target group? Regarding the interface buttons?
Evaluator: Erm... I think it's the same. Just the same.
`Observer:` 7.
Evaluator: That' easy.

4. `Observer:` Now 1 is not meaningful at all and 7 is very meaningful. How meaningful was the feedback given at the end of the exercises?
Evaluator: Erm. Something meaningful. Erm... 6, or something like that, I suppose.
`Observer:` OK. Might the answer be different for users in the target group?
Evaluator: Hm. (incomprehensible) Probably not.

5. `Observer:` On a scale of 1 to 7, where 1 is not helpful at all and 7 is very

helpful, how helpful was the feedback provided for correcting later exercises in the same topic?
Evaluator: Erm... I had to say nothing, probably. Quite helpful. 6, is that what a...
`Observer`: 6. Hm, hm. And might the answer be different for users in the target group?
Evaluator: I don't think so. No.
`Observer`: So, it would be the same.
Evaluator: Yeah. Hm, hm.

6. `Observer`: OK. On a ... 1 is very... not consistent at all and 7 is very consistent. How consistent was the environment's sequencing of exercises to the one in Schoenberg's method?
Evaluator: Erm... Very consistent, I imagine.
`Observer`: 7.
Evaluator: Yeah.

7. `Observer`: Is the <Next> button representing in an intuitive way Schoenberg's left-to-right pedagogical constraint?
Evaluator: Yeah. Hm, hm.
`Observer`: It we put this on a scale, 1 to 7, 7 would be very representative, and 1... you would say that it would be 7 or a little bit...?
Evaluator: Yeah, I mean, given that there are a few bugs...
`Observer`: Hm, hm.
Evaluator: ...it occasionally let me through the gate when I shouldn't have. But yes, as long as ...
`Observer`: ... as long as ...
Evaluator: If it works as a gate where there is a stop, yeah. 7.
`Observer`: OK.

8. `Observer`: OK. 1 is not consistent and 7 is very consistent. How consistent was the environment and its graphical interface to the pedagogical constraints of the method as a whole?
Evaluator: Hm...
`Observer`: So we have other pedagogical constraints like this root positioning ...
Evaluator: Yeah.
`Observer`: at the beginning, and... This positioning, that in fact, I've structured this information from it (the book) is not completely clear as...Erm... Most of the information there is not clear, is... Everything is buried inside (it)...
Evaluator: Yes, that's right. Yes.
`Observer`: in philosophical discussions.

Evaluator: Yeah. Erm... But (incomprehensible) is a bit of Schoenberg's sort of apologia for himself in some ways. No, I think it's pretty consistent. Let's say 6 again or something like that. `Observer:` 6 again. OK.
Evaluator: On a 7 scale.
`Observer:` Hm, hm. On a 7 scale. That's it.

9. (Question 9 was answered after the interaction for the second evaluation study took place, when all the other answers were also revised)

10. `Observer:` 1 is not beneficial at all and 7 is very beneficial. How beneficial was to learning the design decision of taking away from students the responsibility of choosing the chord sequence to work with? I mean that in Schoenberg's method the student is responsible for defining...
Evaluator: (reads aloud the question) Although he ...
`Observer:` So, how beneficial do you think it is for ...
Evaluator: It is beneficial to start with, yes. You need to get rid of it before too long otherwise student's become... Well, yeah, because it becomes like a figured bass. I mean, you might as well must give them the bass note, of course, it's the same.
`Observer:` Hm, hm.
Evaluator: If you are in the root position of chords, you're effectively...
`Observer:` But you have choices. In here (points to chord I on screen) you can go to ....
Evaluator: Your choices are up to pitch. Yeah, yeah. Yes.
`Observer:` ... different octaves for the bass.
Evaluator: Yes, yes.
`Observer:` And sometimes the restrictions of the other movements might impose ... er ... restrictions to your bass at the moment ...
Evaluator: Yes, yes, of course.
`Observer:` ... simultaneously.
Evaluator: But, ahn, it is true to the... So, what was the question?
`Observer:` 1 to 7... How... Sorry.
Evaluator: It's alright.
`Observer:` How beneficial was to learning the design decision of taking away from students this choice of the degrees? 1 is not beneficial, and 7 is very beneficial.
Evaluator: Well, as I said, very beneficial at the start, so.
`Observer:` At the start.
Evaluator: I presume that's what you mean.
`Observer:` Hm, hm. Yeah, yeah. As we were talking about this start.
Evaluator: Yeah, yeah. So, is very beneficial because it's concentrate the man on the other things.

11. `Observer`: The same scale: 1 is not appropriate at all and 7 is very appropriate. How appropriate is the control of student's behaviour? So, I mean that we are first posing exercises like: choose a bass, given the bass choose a soprano, given the bass and soprano choose the, the... alto or the tenor fill the notes. So we are controlling the student's behaviour somehow. So, how beneficial... how appropriate is that control of student's behaviour? 1 is not appropriate at all and 7 is very appropriate.
Evaluator: Erm.. You mean, within the parameters of Schoenberg ...
`Observer`: Yeah.
Evaluator: ... it's appropriate. I suppose I would say that within my own ... in the broader skills (laughs) it's useful at the start. But again, it's ...
`Observer`: Hm, hm.
Evaluator: It might be too constricting but, erm...
`Observer`: For beginners ...
Evaluator: For beginners, yes, yes. It's how is difficult ...
`Observer`: Yeah.
Evaluator: ... to give a straight answer to (laughs). Like a (incomprehensible).
`Observer`: Yeah, yeah. Just not to generalise (laughs). I know what you mean.
Evaluator: Do you need a scale or there is ...?
`Observer`: The scale is 1 to 7.
Evaluator: Something like 5, I suppose. I mean, because I have reservations, I suppose, about the whole ...
`Observer`: Because of the method. Reservations for the method.
Evaluator: But within Schoenberg's parameters is quite appropriate.
`Observer`: The music community in fact, as a whole, they have reservations with Schoenberg.
Evaluator: Yes.
`Observer`: This particular book (shows Schoenberg's "Theory of Harmony") in fact is not well known as far as I know. Everyone talks about it, but they are in fact referring to (Schoenberg's) "Structural Function of Harmony" ...
Evaluator: Right, OK.
`Observer`: ... where there is a chapter of, where this book (Schoenberg's "Theory of Harmony") is summarised in 5 pages, or 6 pages (laughs). So, the pedagogical constraints are not there, and this is a more advanced reading.
Evaluator: Yes.
`Observer`: And this one (shows Schoenberg's "Theory of Harmony") that was intended for undergrads...
Evaluator: Hm.

`Observer:` .... is only used by ...
Evaluator: (incomprehensible) people probably... It's a very... I mean, this is best done, as I did, at the school level, I suspect, or at least (incomprehensible). By the time you get to the university it's very slow and it's.... On the other hand, as a computer program it might be very useful. If you have (to) only see somebody only every week or two weeks and you have to do step by step you wouldn't get very far at the end of the term.
`Observer:` Yeah, yeah.
Evaluator: This I suspect (is) why are people keen to get on to doing real music.
`Observer:` So, basically we are removing Schoenberg's from Schoenberg. Removing Schoenberg ... *Evaluator:* Hm, hm. `Observer:` ... from Schoenberg's teaching (laughs), ... *Evaluator:* From Schoenberg. Yes. Yes. `Observer:` ... the philosophical stuff.
Evaluator: His implication is that it's a mechanical, it's best done as almost a mechanical exercise, in stepwise. When he talks about removing the mystique of the teacher, the..., the..., the theorist, all that sort of thing. `Observer:` Yeah, yeah. *Evaluator:* So, within that parameters is fine, yes. I like the idea. `Observer:` So, it seems that you've read everything that I sent to you (laughs). *Evaluator:* I've read before I came here, so.. `Observer:` OK. Brilliant.

12. `Observer:` Now, next question. Is it better to leave students responsible for getting aural feedback from a musical instrument rather than having it readily available as in the prototype?
Evaluator: You see ..., you mean feedback from the screen, or ... `Observer:` Yeah, so, if you are writing this (shows the score on screen). You wrote. And then you need to move to the piano to play it.
Evaluator: Ah. Yes.
`Observer:` Here we have the <Play> button, and it's just a matter of pressing it and getting the aural feedback ...
Evaluator: Yeah.
`Observer:` ... from what you've done. Is it better this way, or the other way of going to the musical instrument ...
Evaluator: No, I mean, the quality of the sound is poor at the moment, but that can be improved.
`Observer:` Hm, hm. Definitely.
Evaluator: No, I think it's very good to have.
`Observer:` A change of the platform it will be immediate and you can control the parameters. In fact we have control over the instruments, and we can change the patches (shows the menu option that enables the change of the instrument that will play the score). Of course, the piano is the most

appropriate one for this ...
Evaluator: It might not, because you are writing for voices. I mean, if you have ... Have you got voice?
`Observer:` Voice? It's not that good because it's a software synthesiser.
Evaluator: We can try stings
`Observer:` Yes you can try.
Evaluator: (selects the string patch and plays the last sequence) I mean, you can hear that ... you can hear the chords much better. I would have think because, it's not ... When one is writing is not actually for piano, most of the time you are writing for voices.
`Observer:` Hm, hm. So you prefer voices.
Evaluator: I would think so. Yeah.
`Observer:` We have possibilities of ...
Evaluator: Yeah, yeah, yeah.
`Observer:` ... of getting the aural feedback.
Evaluator: You also get the top line much better because on the piano you (incomprehensible) what was coming .
`Observer:` So, back to the question: is it better to leave students responsible for getting this (aural) feedback or is it better to ....?
Evaluator: No. It's better to incorporate it.
`Observer:` Better to incorporate.
Evaluator: Yes. You want to feel it as real music.
`Observer:` Hm, hm.

13. `Observer:` Is Schoenberg's exploration of solutions properly embodied in the prototype?
Evaluator: Erm... So far, yes, yes.
`Observer:` OK. I think this is a matter of only the chords that you are thinking.... you think that they are missing is just a matter of incorporating as long as you are progressing through the course and new chords can be easily be added.
Evaluator: Yes, that's fine. Yes.
`Observer:` So,...
Evaluator: I mean, the question is ... Do you imply that takes a long time even to set this up?
`Observer:` After it's set up it's just a matter of (adding new chords)...
Evaluator: Yes, yes. But I mean, there are all the next stages of introducing inversions, and then introducing other chords,...
`Observer:` But in this situation, for instance, you are exploring, so you can even return and modify new chords, you can change your solution. This is the exploration that I am referring to.
Evaluator: Yeah. It seems fine. Yes.

`Observer`: It seems fine.
Evaluator: OK. Yeah.

14. `Observer`: And the last question: Is it better to leave students responsible for assessing their exercises by themselves, as suggested in Schoenberg's method, rather then receiving didactic feedback after each chord construction?
Evaluator: All right. What does Schoenberg suggest, that they...?
`Observer`: They should assess themselves.
Evaluator: That's right. Erm. If you could incorporate a sort of timer, yes, because you do want the students to assess themselves as well, I think.
`Observer`: Hm, hm.
Evaluator: So you don't want them to press the ... So what happens again when you construct a chord and then press <Next>.
`Observer`: Then you receive...
Evaluator: ...the feedback...
`Observer`: ...like this (points to the screen and reads one feedback message): chord 3, the position of it, and where...
Evaluator: OK. The tendency of the students is not to assess themselves, but to simply press <Next> and see what the machine tells them.
`Observer`: Yeah, yeah. And if the machine does not allow, it's wrong, he tries to fix, without paying attention. So, you are saying that is not that better (to have the exercises assessed by the system)...
Evaluator: I would prefer to have some... I don't know how to incorporate it, but I think it's important for students to assess their own chords before, you know, if possible, before they get the (feedback).
`Observer`: So, it's better for students to assess themselves...
Evaluator: Hm, hm.
`Observer`: ...instead of getting the feedback.
Evaluator: Together with getting feedback. I think it's very good to have the feedback because otherwise they are not learning. But it's...
`Observer`: I see.
Evaluator: It could be too easy for students as it was here, because you told what the right answer is, while if you have some way of....
`Observer`: It's like the calculator.
Evaluator: Yes, exactly.
`Observer`: You use the calculator and you don't learn how to add, and multiply numbers, you rely that much in the calculator.
Evaluator: So, so...
`Observer`: So, probably balancing.
Evaluator: Balancing, yes. I don't know how you would do that, because it's up to the individual student to assess, to look at it first, to decide. But

I found myself at the end not checking and just sort of waiting to get the answer. That's tempting.
`Observer:` Yeah, quite tempting. Like in programming. Instead of thinking about the logic of the stuff, you just... Ah, let's try...and put a bunch of commands to see results.
Evaluator: I suspect for Schoenberg I would believe he would have seen that as too easy an option.
`Observer:` Sorry?
Evaluator: For Schoenberg that would have been too easy an option, to get an instant feedback.
`Observer:` Hm, hm.
Evaluator: He wanted students to analyse it.

Semi-structured Interview Sheet for the Empirical Study on

A Harmony Teaching Environment Interface

Evaluator C: Stephen Doughty

1 Basic Information

1. `Observer`: Describe your background in music.
   Evaluator: Erm... I am a professional musician (laughs).
   `Observer`: And you have a couple of diplomas, is that right?
   Evaluator: I have a couple of diplomas.
   `Observer`: And you are... erm... you are a Bachelor in Music.
   Evaluator: And Master in Music as well.
   `Observer`: Master in Music as well. I see.

2. `Observer`: Have you taught harmony courses?
   Evaluator: I have. Yes.
   `Observer`: Hm, hm. For students in which year?
   Evaluator: For both undergraduate and postgraduate.
   `Observer`: At the University?
   Evaluator: At the University.
   `Observer`: At the University.
   Evaluator: And privately. And privately.
   `Observer`: I know (laughs).
   Evaluator: (laughs).

3. `Observer`: What was the main textbook that you were I using?
   Evaluator: There wasn't derived from a textbook specifically but, just from erm... examples created through the University erm... teaching system.
   `Observer`: Hm, hm.
   Evaluator: There wasn't based in one textbook in particular...
   `Observer`: I see.
   Evaluator: ...just on practical example.
   `Observer`: So, it's the very same approach as John Kitchen and Noel O'Regan.

Evaluator: (incomprehensible) Yeah.
`Observer:` They, they... took part...
Evaluator: Yeah. Hm, hm.
`Observer:` ...on this, this evaluation as well last Friday, so...

4. `Observer:` On a scale of 1 to 7, where 1 is not important at all and 7 is very important, how important is the harmonisation of melodies for the global assessment of first years... first year harmony students? So, harmonisation of melodies.
Evaluator: How important is the harmonisation of...
`Observer:` For first years' harmony students. For the assessment of them.
Evaluator: I would probably say 4 to 5, perhaps.
`Observer:` Hm, hm.
Evaluator: Erm... I think that the harmonisation gives a reason(able) idea to your sort of basic musical feeling, I think, in the background. And of course if that's not what you are interested in and it is perhaps not so quite important. If they had there for example, oboe player, then harmonising melodies is not all that important because you don't do it all the time.
`Observer:` OK.
Evaluator: That's probably 4 to 5, perhaps.
`Observer:` OK. But the oboe player is supposed also to have... to cours... to take the course in harmony.
Evaluator: Indeed, yeah. Hm,hm. But he may not find it as useful as...
`Observer:` as useful for...
Evaluator: as for keyboard players.
`Observer:` Hm, hm. I see. So, you, you think that 4 to 5 is OK for the harmonisation of melodies.

5. `Observer:` And the same scale, erm..., how important is the harmonic analysis of musical pieces from the eighteenth and nineteenth centuries to the harmony teaching?
Evaluator: Erm... I would probably say 6 to 7, then. Yeah.
`Observer:` I see.
Evaluator: Yeah. That's where all come from...
`Observer:` Hm, hm.
Evaluator: ....kind of thing.
`Observer:` OK.

6. `Observer:` Have you used Schoenberg's "Theory of Harmony" in your teaching?
Evaluator: Not in my teaching. No. But I've used it for reference.
`Observer:` Hm, hm.
Evaluator: Just for interest.

`Observer:` I see.

7. `Observer:` Do you think it is feasible to run an undergrad course on harmony centred around this book?
   Evaluator: I don't see any reason why not. Is... It is just one of the..., the main books on the subject.
   `Observer:` Yeah.
   Evaluator: I would think so. Yes.
   `Observer:` OK. I'm wondering because of that...the rates that you gave in the previous questions erm...
   Evaluator: Right.
   `Observer:` ...and these previous questions they are dealing with these paradigms that Schoenberg is not using at all in his teaching.
   Evaluator: Hm.
   `Observer:` He does not harmonise melodies and he does not make a harmonic analysis...
   Evaluator: I think...
   `Observer:` So, from this point of view, if you give so much importance to these subjects, erm... this question is...
   Evaluator: I think... My feeling is that being able to harmonise a melody is all very well. Being able to harmonise it, you know, and keeping certain styles or, erm..., so you can do it. I mean, I am a continuum player...
   `Observer:` Hm, hm.
   Evaluator: So, if I have to harmonise stuff in an appropriate particular style, if I had not studied eighteenth and nineteenth centuries then I would be playing in an entirely... in a vacuum.
   `Observer:` OK, I see.
   Evaluator: So I think it is quite important to know what has been (done) before.
   `Observer:` Good. So, thanks for the answers. Perhaps now we can start reading the handout.

2 Questions (Semi-structured Interview)

1. `Observer`: Do you think that the music notation interface of the environment is appropriate for the method?
   Evaluator: Yes. Yeah, yeah.
   `Observer`: OK.

2. `Observer`: Now we have a number of questions within the scale of 1 to 7. On this scale of 1 to 7, where 1 is very difficult and 7 is very easy, how easy did you find using the mouse to insert and delete notes?
   Evaluator: Erm... 6.
   `Observer`: OK. Might the answer be different for users in the target group, beginners?
   Evaluator: Erm... erm... No, probably not, actually, no. Because beginners would be familiar in using a computer.
   `Observer`: I see. OK.

3. `Observer`: Now 1 is very difficult and 7 is very easy. How easy did you find using the interface buttons to complete exercises?
   Evaluator: Very easy. So, erm..., 7.
   `Observer`: Might the answer be different for users... (in the target group)?
   Evaluator: No.
   `Observer`: So, the same answer.

4. On a scale (of) 1 to 7, where 1 is not meaningful at all and 7 is very meaningful, how meaningful was the feedback given at the end of exercises, or even in the middle of them?
   Evaluator: Erm... It gave you the... It gave you erm... suitable alternatives.
   `Observer`: Sorry?
   Evaluator: It gave you alternatives to what you had on the page, so...
   `Observer`: Highlighting what the possibilities are.
   Evaluator: Yeah. I suppose... Let's say, 6.
   `Observer`: Again, might the answer be different for users in the target group?
   Evaluator: Erm... Possibly, yes, possibly.
   `Observer`: But in which sense? A higher or a lower...
   Evaluator: They might not understand it exactly. For example, perhaps the G3, G4, whatever, that sort of thing, perhaps...
   `Observer`: I see. It would be less meaningful for them.
   Evaluator: It could be. Yeah, yeah.
   `Observer`: Have you got a guess for...
   Evaluator: Erm...
   `Observer`: ...using your experience as a harmony teacher?

Evaluator: (laughs) Let's say 4, I think.

5. `Observer`: On a scale (of) 1 to 7, where 1 is not helpful at all and 7 is very helpful, how helpful was the feedback provided for correcting later exercises in the same topic?
   Evaluator: Yes, it was helpful. So, 6.
   `Observer`: 6. Regarding the target group, might the answer be different?
   Evaluator: Erm... I think it was quite self explanatory, so let's say 6 again.

6. `Observer`: OK. 1 is not consistent at all and 7 is very consistent. How consistent was the environment's sequencing of exercises to the one in Schoenberg's method?
   Evaluator: Er... Let's say 5, because of the interesting moments we had.
   `Observer`: Erm... But... we are talking about the sequencing.
   Evaluator: Oh, I see (what) you mean.
   `Observer`: The sequencing: the bass...
   Evaluator: I see.
   `Observer`: ...soprano, etc, and then the missing tones.
   Evaluator: Alright. That was... that was a 7, then... 7 (making sure the observer had the proper answer written on the semi-structure interview sheet).
   `Observer`: Oh, yeah, yeah. 7 (laughs).
   Evaluator: (laughs)
   `Observer`: Sorry. In fact everything is (being) recorded, and I will collect the information from there, the minidisc.

7. `Observer`: Is the <New> button representing in a natural way Schoenberg's left-to-right pedagogical constraint?
   Evaluator: Erm... What does that mean (laughs)?
   `Observer`: In an intuitive way, I think. I think it is a better word. When you have a sequence...
   Evaluator: The <New> button?
   `Observer`: The <New> button, yeah. Oh, sorry, the <Next> button. That's the <Next> button. That's the button when you move from the... from one chord to another.
   Evaluator: Yes, it is.
   `Observer`: So, is completely different from your approach of harm... doing things.
   Evaluator: Hm, hm.
   `Observer`: First the bass, and then you fill...
   Evaluator: Yeah.
   `Observer`: So, Schoenberg is very clear in this respect. You need to write a chord, after you finish (it) you move to the next one. You will not think

on (the) bass line...
Evaluator: No.
`Observer:` ...in advance. You think on the fly.
Evaluator: But the Schoenberg's method, you don't want to put the soprano next.
`Observer:` Erm... Only for the first chord.
Evaluator: Alright, alright. OK.
`Observer:` Only for the first chord. For the other ones you need to keep the common tones...
Evaluator: Right. OK.
`Observer:` ...preparing and resolving with the seventh degree, it would be a different...
Evaluator: (reading aloud the handout) ...in an intuitive way Schoenberg's left-to-right pedagog.... Yes. I think so. That's a complicated question (laughs).
`Observer:` If you... if you had this scale where 1 is not representing well, and 7 is representing very well, which number would you give to it?
Evaluator: I still don't really understand the question, actually.
`Observer:` I see.
Evaluator: What do you mean by left-to-right pedag... pedagogical constraint?
`Observer:` Pedagogical constraint?
Evaluator: What does that mean?
`Observer:` This means that, for instance, in your teaching, you use the bass, you define a bass (line) and then you fill the gaps in the middle in a different way than Schoenberg's.
Evaluator: Sure, sure.
`Observer:` This is a pedagogical ah... erm... principle that he's using. We can represent this as a pedagogical principle.
Evaluator: Right.
`Observer:` That means that you write a chord, and then you connect to the next one, third one, fourth...
Evaluator: Alright. OK.
`Observer:` You (do) not write the bass line.
Evaluator: Right.
`Observer:` In your case, your pedagogical constraint is to write the bass (line) and then to fill in the middle. Is a different pedagogical principle.
Evaluator: I th... Yeah.
`Observer:` Is this principle of left-to-right writing from Schoenberg well represented in our environment through the <Next> button?
Evaluator: Yes. It is in that case. Yeah.
`Observer:` Is it clear now the question?

Evaluator: Yes, it is now, yeah. I also think, see, my way of achieving common tones and line, if you like, it would go that way (draws on screen, with the finger, a bass line).
`Observer:` Hm. hm.
Evaluator: So, I would write the bass line and so I would make sure that the bass line is good, whatever. The alto line would go that way (draws on screen, with the finger, a soprano line).
My personal feeling is that if you do this chord (points to the first chord of the sequence on screen)...
`Observer:` Hm. hm.
Evaluator: ...then this chord (points to the second chord on screen)...
`Observer:` Hm. hm.
Evaluator: ... and this chord (points to the third chord on screen), and this chord (points to the fourth chord on screen), all that way (points to the screen making a vertical movement with the hand)...
`Observer:` Yeah.
Evaluator: But I prefer to work that way (points to the screen making a horizontal movement with the hand). Erm...
`Observer:` I see.
Evaluator: That's why... I find it quite erm... parado... paradoxical, is that right?
`Observer:` Hm, hm. Yeah, yeah.
Evaluator: ...because he says you should achieve common tones and you only are allowed to do one chord at a time.
`Observer:` Yeah. But when you are moving to the next one you think... you're trying to be... erm...
Evaluator: By this very nature, as you said yourself, in order to write this chord I need to work out what this one would be first.
`Observer:` Hm, hm.
Evaluator: Or to write that bass note I need to work out what the other ones were. So, I can't write one chord when I don't know where the next one is. If you just said to me... If you give me one chord and said: write a chord I, as we did in the previous exercise then I discovered that the next chord you couldn't do that.
`Observer:` Oh yeah.
Evaluator: And that's a waste of effort.
`Observer:` Yeah.
Evaluator: Whereas if I could have writen the whole line that way (points to the screen making a horizontal movement with the hand) then, then...
`Observer:` So, you are trying to challenge this pedagogical principle from Schoenberg, somehow. Yeah. As you wrote a chord and then you start on the following one, you were not able to provide a good connection for it,

and you have to redo the previous one, so...
Evaluator: That's right. Yeah, yeah
`Observer`: But the student first will know the sequence that he's working with. So...
Evaluator: You have... you have to read left-to-right before doing anything.
`Observer`: The student is in fact responsible to define the sequence, as we'll see later on, so...
Evaluator: OK.
`Observer`: He knows already the sequence and he's about to write the first one....
Evaluator: So, by... by knowing the sequence anyway you have to know where the bass notes are. So, therefore write them in. (laughs)
`Observer`: Ahn, I don't quite agree. (laughs)
Evaluator: Anyway...
`Observer`: So...
Evaluator: It does represent.
`Observer`: In a scale 1 to 7, 7 is a good representation?
Evaluator: Yes. It should be...
`Observer`: It would be number 7?
Evaluator: Yeah.

8. `Observer`: 1 is not consistent at all and 7 is very consistent. How consistent was the environment and interface, a graphical interface, to the pedagogical constraints of the method? So, in addition to this left-to-right constraint, we have this, ahn..., we have other pedagogical constraints implicit like: connecting common tones, and then... The sequencing of the the exercises is related to the pedagogical constraints as well. I'm talking about it as a whole. Is Schoenberg pedagogy well represented in the environment?
Evaluator: Judging by the fact that situation on those two chords...
`Observer`: Hm, hm.
Evaluator: that I could actually do something that was illegal, is not absolutely a hundred percent consistent.
`Observer`: I see. Because... er... because of the bugs.
Evaluator: Oh yes.
`Observer`: OK, ok. So, it was not a hundred percent...
Evaluator: No.
`Observer`: ... but if... if it did not have this bug, and you were stuck and not moving to the right...
Evaluator: Yeah.
`Observer`: ...as you were supposed to be. I don't know how this (the bug) happened.
Evaluator: (laughs)

`Observer:` My idea was not...
Evaluator: Oh, no. Of course. I'm just commenting on the system as it is.
`Observer:` OK. Comment as it is. How... how... Which number would you give...?
Evaluator: Probably 6, then. I wonder if... if... it is in the first chord only, you have to do the bass, then the soprano...
`Observer:` Yeah.
Evaluator: ...is there any way of not letting you fill the inside parts until you've done the soprano?
`Observer:` Of course. As... Do you remember the beginning?
Evaluator: Hm, hm.
`Observer:` You started with the bass. The next exercise, the bass was given and the soprano was given... was asked.
Evaluator: Before the subsequent exercises.
`Observer:` Yeah.
Evaluator: Because I could fill the chord from the bottom-up, and it would let me.
`Observer:` I decided not to do that (constraining the order on the discovery mode exercises), because sometimes students think on a chord as a whole.
Evaluator Right.
`Observer:` And they start to fill the other way round.
Evaluator: But that's not allowed according to Schoenberg.
`Observer:` Is not that is allowed. He says: you need to think like that. You need to think...
Evaluator: Alright, OK.
`Observer:` You need to think... and not the actions, so. What is in your mind is repre...
Evaluator: If the system didn't let you put the tenor...alto and tenor and tell you to put the soprano when in the first chord, that would reflect...
`Observer:` Even more.
Evaluator: ...it would enforce the thought upon you. Yeah.
`Observer:` Yeah. I thought about that, but I thought it was too much imposition into the student's mind, because...
Evaluator: But that's the constraints.
`Observer:` Definitely.
Evaluator: That's the reason for the sequencing I was trying to enforce the thinking. The thinking of, not acting upon the interface.
`Observer:` I asked John Kitchen and Noel to do that (sequencing), and they didn't do that. First bass, then soprano... No way... (laughs).
Evaluator: We all do the same... We all do the same ways. (laughs).
`Observer:` You are too.. too much... too knowledgeable for that.
Evaluator: (laughs) But certainly, if... if...

`Observer`: I agree with you.
Evaluator: ...if it didn't let you, then, or as soon as you put an alto line it came up with a warning, or something. I don't know.
`Observer`: Hm, hm. For instance, there are technical difficulties for that. If you click on a note, you are thinking that this could be a bass. But it could be an alto as well. Who is saying that is the alto or bass? Only when you put the second note is that you know.
Evaluator: They all put the bass first.
`Observer`: No, but, I mean... When you click on a note in this stave (points to the bass stave on screen)...
Evaluator: Yeah.
`Observer`: ...you never know which voice is this till the moment you click the second one. Can you understand me?
Evaluator: Yes. Absolutely. But in Schoenberg's teaching they always put the bass note first. So therefore the computer will read the... Well, the first note you put has to be the bass.
`Observer`: Yep.
Evaluator: And therefore it wouldn't let you put anything more than that.
`Observer`: OK. Let's think: chord I. We have nothing. And you click on this C.
Evaluator: Hm, hm.
`Observer`: The system thinks: OK. This is the bass. I'm asking the bass and he is putting the bass. But the next note the guy clicks the C below.
Evaluator: But that's a mistake of the student, and not of the system.
`Observer`: The system was thinking that it was the bass.
Evaluator: But then a warning would come saying that this was an incorrect move. The next line, the next note you should put is a soprano.
`Observer`: Yeah. At some point I thought about enforcing this...
Evaluator: Hm.
`Observer`: ...but I thought it was too much imposition, but I agree. So, this deviates me from the maximum mark for the pedagogy.
Evaluator: No, it's still OK (laughs). OK.

9. `Observer`: So, another (design) decision that's addressed on the next question. The student is supposed to write the Roman numeral sequence but he's not writing. We are giving to him.
Evaluator: Right. OK.
`Observer`: 1 is not beneficial at all and 7 is very beneficial. How beneficial was to learning the design decision of taking away from students the responsibility of choosing the chord sequence to work with?
Evaluator: Erm... (reads aloud the handout) how beneficial...
`Observer`: Is it clear the question?

Evaluator: Yes, I think so. Again, there's pros and cons. Erm. Presumably Schoenberg recommends a chord sequence, does he? Or can you choose any chord for the next one?
`Observer:` Hm, hm. In this case of common tones, for example, he recommends: connect chords having common tones in sequences up to 6 chords.
Evaluator: Right. Any chord?
`Observer:` Any chord. 1 , 3 , 5 .... as we did, 1, 6, 4,... as long as they have common tones, and these (the sequences) start and end at the first degree. that's OK. That's a valid sequence for you to try to have a go and explore the possible solutions.
Evaluator: A lot of the exercises have the same chord sequence.
`Observer:` I was intending the open and close position.
Evaluator: Right. Perhaps... perhaps... There was about 6 of each, I think. Perhaps of ...one... one.. one open and one closed and then change the chord sequence. Because, I mean, for myself, I found wherever there was 1, 3, 5...
`Observer:` Hm, hm.
Evaluator: ...there's a limit of how many bass lines you can write.
`Observer:` Yep.
Evaluator: So, perhaps, every two screens change the chord sequence, a random selection of chord sequences.
`Observer:` So, ermm.. the teacher would have flexibility to define the exercises, and create them in a file, and adapt to generate new...
Evaluator: Or the computer can generate by itself. I mean, if the student can choose any chord sequence as long as they connect...
`Observer:` Hm, hm.
Evaluator: ...there is no benefit in enforcing the chord or not enforcing the chords. Erm...
`Observer:` Hm, hm. This means...
Evaluator: The benefit of the student chose the chord and played it back, he will be able to hear whether it sounded good or not good.
`Observer:` Hm, hm.
Evaluator: You know, if he had, I don't know, 1, 7, I don't know, 1, 7, 4.
`Observer:` Not 1, 7. 1, 7 is not allowed (laughs).
Evaluator: ...or something like that. Erm... I can't think some obvious... Some sequences would sound better than others. But anyway, is not about how it sounds, is all about connections, isn't it?
`Observer:` Yeah. Everything is about connection. How to connect things properly, and etc.
Evaluator: Yeah.
`Observer:` And the question is erm... we are taking away (from students) this decision of choosing (the Roman numeral sequence). Is this beneficial

or not to the learning?
Evaluator: Erm... I would say 5.
`Observer`: OK, so.
Evaluator: Medium beneficial.
`Observer`: Medium beneficial.

10. *Evaluator:* How appropriate is the control of the student's behaviour? Is it how appropriate is to control the student's behaviour?
`Observer`: No. Is the control of the behaviour that we are imposing over the students through the environment, so..
Evaluator: If the purpose of the exercises to enforce Schoenberg's thinking...
`Observer`: Hm, hm.
Evaluator: ...then it is entirely appropriate.
`Observer`: OK.
Evaluator: If the student doesn't want to learn it, that's his problem. If is that what you are trying to enforce, then it is very appropriate, yeah.
`Observer`: So, you would say that, in this case?
Evaluator: 7.
`Observer`: 7. OK. So, it's very appropriate.
Evaluator: If it's that what you are trying to do. Yeah.

11. `Observer`: Now:Is it better to leave students responsible for getting aural feedback, from a musical instrument, when he is writing on paper...
Evaluator: Hm.
`Observer`: and they need to listen to what they created, rather than having it readily available as in the prototype? So, I mean that: is it better to have this <Play> button for you to play and get the aural feedback from what is written on screen at once...
Evaluator: It's good. I think it's better.
`Observer`: So, again, in a scale of 1 to 7, if 7 is the maximum... Ah, no, no. I think this is... does not make sense.
Evaluator: It is better to have it.
`Observer`: It is better.
Evaluator: What does this wee footnote at the bottom say? (start reading aloud the footnote at page 270, and keeps reading it silently) This decision... Which decision?...
`Observer`: I'm providing some justification for taking the control, otherwise the students would try to... or even write chords that were not supposed to be written at this particular stage of the learning , and so on...
Evaluator: Yes.
`Observer`: And this, yes, you already know.

12. Is Schoenberg's exploration of solutions properly embodied in the proto-

type? The basic point erm... you can read at the preface. I think I didn't give to you.
Evaluator: Hm.
`Observer`: He says that the student must explore. Search is the keyword for this learning of harmony, as long as he follows this kind of method.
Evaluator: Search.
`Observer`: Search, yeah. You create your sequence by yourself, you start to creating the notes, and connecting by yourself, and assessing. So, you are looking for solutions, and...
Evaluator: Hm.
`Observer`: ...and creating your own questions.
Evaluator: OK.
`Observer`: (laughs) Is completely different from the...
Evaluator: But, I think (incomprehensible) then, it would be better if the sequences of chords change more regular..., more frequently. (incomprehensible) to get the students more opportunity to search for solutions. I found...
`Observer`: It was not the aim, in here, to provide a rich variety of sequences...
`Observer`: Right.
Evaluator: ...it was just for you to interact and the exercises we can create whatever sequence you like and...
`Observer`: Because I found it...
Evaluator: For the real students we need to put, I agree with you, a very carefully selected repertoire of sequences.
Evaluator: Sure.
`Observer`: in order to give you more, erm...
Evaluator: Because I find, I find the challenge of beating the restrictions, because we have four or five versions of the same chord sequence. Trying to put something different it was quite difficult to find something different. So, rater than encouraging one to explore different erm... solutions.
`Observer`: OK. Putting a bigger variety.
Evaluator: The difficulty was actually finding the ones based, I mean, when you have a chord sequence that goes I – iii – V, is very difficult to get away from a bass line that goes up in thirds.
`Observer`: Yeah. I see. I – iii – V.
Evaluator: You can really avoid it.
`Observer`: And (from) the iii to the other V it would be a too big leap if you are going down.
Evaluator: Again, according to the Schoenberg, you know, the sixth...
`Observer`: The sixt...
Evaluator: ...so, rather than having you to explore, you must do this pat-

tern.
`Observer`: So, a richer variety of exercises would be more interesting. But, in this particular kind of exercise, my question is: Is this a embodiment, if you like, for one particular exercise, not the sequencing. Is this exploration within an exercise, properly embodied?
Evaluator: I would think so. Yeah, I think so.
`Observer`: OK.
Evaluator: In the moment that comes across, it has been quite restricted, rather than being... having you to explore.
`Observer`: Hm, hm. I see.
Evaluator: Is a difficult balance. I mean, theoretically it should perhaps be more restricted and you can only put the bass note first, and you can only put the soprano note second, and it could have even more restrictions.
`Observer`: Yeah.
Evaluator: And, on the other hand, erm... you're restricted particularly if you have repeat of chord..., chord progressions time after time after time. You're quite restricted by that.
`Observer`: Yeah.
Evaluator: Because there is a limit, obviously, of what different notes you can put in.
`Observer`: Yeah.
Evaluator: So... On the other hand, if you have anything more complicated again, so...
`Observer`: I agree with you that the choices for the sequences are not that rich (laughs).
Evaluator: Can I go backwards in a sequence?
`Observer`: No. You can't. But I can reproduce later what you did, but not write now. I need to analyse the files that were created while you were interacting.
Evaluator: OK. Does it create new files while I go on?
`Observer`: Yeah, yeah. Your actions are being... were registered. I can now read the files and recreate manually the chords.
Evaluator: Alright. OK.

13. `Observer`: And the last question: is it better to leave students responsible for assessing their exercises by themselves, as suggested in Schoenberg's method, rather then receiving didactic feedback after each chord construction?
Evaluator: Do you mean didactic by having a teacher? Is that what you mean?
`Observer`: No. The didactic feedback from the environment.
Evaluator: All right. OK.

`Observer`: So, if something is wrong, some messages occur showing the possibilities of the next... of the chord that you've have just finished. Showing you the mistakes. The question is: Schoenberg suggested you to write, to get aural feedback, and assess yourself the exercise as well.
Evaluator: Right. OK.
`Observer`: The student needs to...
Evaluator: I think it is better if you have some feedback of what's right and what is wrong.
`Observer`: OK. I think that's it.

Appendix C

Published Papers

The following papers have been published in connection with the research described in this dissertation. They are reproduced here with permission.

Brandão, M., Wiggins, G., and Pain, H. (1999). Computers in Music Education. In *Proceedings of the AISB'99 Symposium on Musical Creativity*, pp. 82-88, Edinburgh, Scotland. ..... page 311

Brandão, M., Pain, H. and Wiggins, G. (1999). An Intelligent Learning Environment for Musical Harmony. In Lajoie, S. and Vivet, M., editors, *Proceedings of the 9^{th} International Conference on Artificial Intelligence in Education*, pp. 626-628, Le Mans, France. ..... page 318

Brandão, M., Wiggins, G., and Pain, H. (1999). Computers in Music Education. In *Proceedings of the AISB'99 Symposium on Musical Creativity*, pp. 82-88, Edinburgh, Scotland.

Computers in Music Education

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Abstract

This paper provides a survey of the applications of computers in music teaching. The systems are classified by musical activity rather than by technical approach. The instructional strategies involved and the type of knowledge represented are highlighted and areas for future research are identified.

1 Introduction

There have been numerous attempts to use computers in music education. As a result of the highly interdisciplinary nature of the field, these applications use different and sometimes contrasting approaches. This paper classifies applications by activities involved in musical teaching, and addresses the instructional strategies, if any, involved. The categories considered are computer applications intended to:

- teach fundamentals of music;
- teach musical performance skills;
- perform analysis of music;
- teach musical composition skills.

Applications in which the computer fulfils only an instrumental role such as sequencer and music notation packages will not be covered by this review; our focus is on applications in which the student is encouraged to freely explore educational environments and micro-worlds or is guided through an instructional task.

Music education applications use a range of techniques from Computer Assisted Instruction (CAI) to Intelligent Tutoring Systems (ITS) [1] in conjunction with different instructional strategies. Whilst this is a continuum, differences between these approaches at the extremes will be considered here. Contrasting with ITS, CAI systems present a limited teaching strategy, as they have no explicit representation of the knowledge to be taught or ability to reason about it, and cannot differentiate between different students. On the other hand, an ITS basically consists of an instructional environment containing three kinds of knowledge (Burns and Capps, 1988): (i) *expert knowledge* of the domain being taught, that is, the ITS should "know" the subject matter well enough to be able to draw inferences and solve problems in that specific domain; (ii) *student diagnostic knowledge*, meaning that it should be able to understand the student's approach to the knowledge, detect and correct possible misconceptions, and (iii) *curricular knowledge*, in such a way that it should be able to reduce the difference between the expert and the student knowledge by means of specific pedagogical approaches.

In the next section we describe the instructional strategies that have been used in educational software design. In sections 3, 4, 5 and 6 we describe applications according to the musical activities involved, and in section 7 we conclude providing a summary and identifying areas for future research.

2 Instructional Strategies

A widely accepted classification of theories of human learning distinguishes between *connectionist* (or *behaviourist*) and *cognitive* approaches (Child, 1973), and it is particularly meaningful in relation to educational software design. While connectionist theories treat learning from the point of view of links between stimulus and response, cognitive theories emphasize the functioning of the brain and how cognitive structures modify the learner's behaviour.

Figure 1 shows the relationship, slightly adapted from Sorisio (1987), between the most common *Instructional Strategies* that have been used in educational software design and their relationship with the basic classes of the theories of learning.

Each one of these instructional strategies presents some important features:

- Programmed Learning: based on the work of Skinner (1961) in *operant conditioning*, it forms the basis for CAI. The idea behind programmed learning results in presenting frames with pre-stored material to the student. Responses to some questions should be given by the student, with the system providing comments according to the student's answers, which are simply matched to pre-stored expected responses.

[1] We will use this term throughout this paper to refer to the general class of intelligent educational tools. Other terms frequently used by researchers in the Artificial Intelligence and Education (AIEd) area include Intelligent Learning Environments (ILE), Intelligent Computer Assisted Instruction (ICAI), and so on.

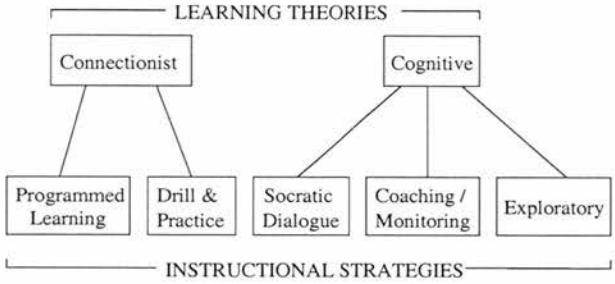

Figure 1: The relationship between learning theory classes and the most common instructional strategies found in educational software

- Drill & Practice: This strategy involves repeating a sequence of activities until the sequence is spontaneous, usually by means of a more interactive CAI to motivate the student.
- Socratic Dialogue: This is a discovery-learning strategy that relies on educational interactions in which the tutor tries to force the recognition and correction of misconceptions.
- Coaching/Monitoring: This is a strategy based on the engagement of the student in a task, while keeping track of the student's activities and giving advice when suboptimal behaviour is identified.
- Exploratory: This discovery-learning strategy encourages the exploration of a domain and usually does not include a direct tutorial component.

3 Teaching Fundamentals of Music

Most existing programs related to Music Education have concentrated on activities such as teaching Music Notation or performing "aural tests" involving recognition and dictation of rhythm patterns, musical intervals, melody patterns, chord qualities and harmonic progressions (Hofstetter, 1988). Computer-based practice allows individual students to practice in less stressful conditions if compared to group-based practice, as research suggests that students may feel less anxious about performing without a human audience (LeBlanc et al., 1997).

The most usual approach to this kind of teaching is the CAI. In fact, this was one of the first uses of computers in education in general (O'Shea and Self, 1983). The branching programs involved must consider every possible path through the frames being presented to the student. As the number of possible routes can become very large, the preparation of this kind of material normally requires a huge effort. To minimise this effort a template could be used, instead of pre-storing the questions and answers. This technique, named *generative computer assisted learning*, could control – in a restricted sense – the subject and level of difficulty of the next example according to some pre-specified strategy.

Earlier computer-based music instruction applications are reviewed by Gross (1984), and the use of CAI for this kind of teaching is revealed to be of great value, particularly in drill and practice of basic skills. A paradigmatic example of CAI in music is the GUIDO system (Hoffstetter, 1975; Hofstetter, 1981), which was used also to practise and test aural skills. Musical dictation concerning musical intervals, melody, chords, harmony and rhythm are overseen by GUIDO. These activities were accomplished through a four voice synthesiser and a touch sensitive display, with the student being invited to select an answer that best describes what he thinks he has heard. Based on the student's responses, GUIDO selects the next material to be presented and acts also on the speed of dictation or the time allowed for the answers to be given.

A significant number of commercial music instruction applications such as MiBAC Music Lessons, Music Ace and Practica Musica, most of them for teaching fundamentals of music, are reviewed by the Nackid (1996). While most of these applications use multimedia presentation techniques and MIDI devices extensively, the reviews indicate again the role of computers as highly specialised multiple choice questionnaire administrators, and the use of programmed learning and drill & practice continues to dominate this kind of teaching. However, an aural training system intended as a tool with which to experiment with different instructional strategies for ear training is currently being developed (Trewin, 1999, personal communication).

4 Teaching of Musical Performance Skills

The activities involved in the teaching of fundamentals of music may be viewed as *supportive* to the teaching of musical performance skills. These activities alone do not significantly improve the performance ability of the students (Swanwick, 1979), and other aural abilities relevant to musical performance should be developed. In this section, we describe some attempts to improve abilities such as "playing by ear" and using aural feedback to correct one's own performance.

The Tunemaster program (Kirshbaum, 1986) addresses the ability of "playing by ear", with the student being invited to play back a melody generated by the system using a touch-tablet. There is no need for previous knowledge of conventional music notation and the student is motivated through the engagement in a computer-based game.

The difficulty that students experience making fine adjustments in their own performances are addressed by Lamb and Buckley (1985) and Yoshinori and Nagaoka (1985). Both approaches use *visual feedback* in the form of a piano-roll graphical interface, and the difference

between them is that the latter also presents a graphical display of expert performances. A similar approach was also used in the Piano Tutor Project (Dannenberg et al., 1990), which is an ITS for teaching the psycho-motor skills of piano playing. Its approach also relies on giving tutorial feedback on the accuracy of the novice's piano performances, but the system is supported by interactive video-disks of a human teacher and a matcher for comparing the student's performance with pre-stored expert performances. Score-following techniques are used as a basis for detecting student errors, and the student model enables instruction to be tailored to the needs of the individual student.

The development and improvement of music performance skills relies on tools with aural and visual feedback as central elements. ITS approaches supported by expert performances and score-following techniques are suitable for helping the improvement of the interpretative abilities of students as in INTERPRET (Baker, 1992), but only within the limited range of previous example pieces. The understanding of the higher level reasoning of real performers could help extend the range of the performance skills beyond pre-stored example pieces, and this was partially addressed in pianoFORTE system (Smoliar et al., 1995). A model for expressiveness in performances was developed with the help of piano instructors, and this knowledge was encoded in the system. Student's performances on MIDI keyboards are captured and visual feedback concerning expressive performance aspects such as tempo, synchronisation, dynamics and articulation are presented to the student on the original score.

5 Computers in Music Analysis

Music analysis deals with the determination of the constituent elements of a musical structure and the investigation of the functions of these elements within that structure (Bent, 1987). As a result of the obvious relationship of music analysis theories with music aesthetics and compositional theories, different views of the nature of music or the role of the human intellect with regard to music are embedded in them. This relationship explains why some music theories are mutually exclusive with other theories.

In this section we give a summary of the use of computers in music analysis as a tool for teaching or as a procedure for investigation. The applications reviewed have been used to test music theories (Baker, 1989a,b; Robbie, 1994), to check the authorship of musical pieces (Gross, 1975), or even to identify where in musical pieces established rules were observed or broken (Blombach, 1981). Computers in music analysis are typically used for event counting, sorting, pattern recognition and statistical analysis (Alphonce, 1980). All these programs recognise occurrences of pitches, notes values, intervals and also patterns and combinations of the previous musical elements.

One of the first attempts to use computers to assist in music analysis was made by (Gross, 1975). She developed a set of routines for melodic and vertical pattern scanning, thematic tracing, harmonic analysis, set theory and for keeping a cumulative count of results. Representative pieces from different musical styles composed by Bach, Haydn, Chopin and Dallapiccola were analysed, and the results were, for the most part, accurate and provided useful quantitative data.

A less generic music analysis tool intended to test the validity of music theory textbook statements about Bach chorales was developed by Blombach (1981). With this tool, it is possible to determine the range of each of the four voices, the number of times pairs of voices cross, the occurrences of parallel perfect fifths and to examine resolutions of tritones. Students find these exercises especially satisfying if they prove the textbook author's discussion inaccurate, imprecise or incomplete (Blombach, 1981).

Some aspects of the theory for tonal music analysis proposed by Heinrich Schenker (1867-1935) were implemented by Smoliar (1971, 1980) as a framework. This theory is centred on a principle of reduction (Cook, 1987; Monelle, 1992; Sloboda, 1985), in which a musical piece can be viewed as a large-scale embellishment of a simple underlying harmonic structure. Smoliar's framework enables a music theorist interactively to formulate an analysis through a compound of Schenkerian transformations.

Other theory-oriented attempts (Baker, 1989a,b; Robbie, 1994) involving knowledge-based systems have implemented aspects of the Generative Theory for Tonal Music (GTTM), one of the most influential theories of tonal musical structure (Lerdahl and Jackendoff, 1983). This theory is a step toward the understanding of musical cognition, improving on Schenker from within the paradigm of generative transformational grammar. But research should be carried out to achieve an even more complete formalisation of the principles by which the listener assigns structures to a musical piece. Some ambiguity arises if we notice the different ways that a piece of music is heard by different people, and this is taken into account by the transformational rules of GTTM. The system proposed by Robbie aims to derive interactively the groupings from a tonal piece according to the grouping component of GTTM, while Baker deals also with the time-span component.

Probabilistic and knowledge-representation based techniques supported by established music theories are the dominant approaches to music analysis. The next section presents a greater diversity of approaches to the task of music composition, as a result of this domain's more open-ended nature.

6 Computers in Music Composition

In this section, we consider applications of computers in music composition ranging from interactive educational games to specialized ITS. Teaching strategies from sim-

ple concept presentation to more exploratory approaches exist, and potential users range from novices to experienced composers.

Music Logo (Bamberger, 1974) is a representative example of the use of an interactive educational game in music composition. Its aim is to apply the ideas of the Logo Language to music, where the student learns through modelling – building and testing models. Experiments involving manipulation of musically meaningful elements support Bamberger's claims about the benefits on the construction and improvement of the pupil's musical knowledge through play (Bamberger, 1991). Some other open-ended microworlds applying Logo techniques to music composition have been built, such as that of Gargarian (1993), LOCO (Desain and Honing, 1986) and Object LOGO (Greenberg, 1988).

Other authors present interface-oriented approaches, such as a musical game involving transformations of sketched freehand curves on staves (Lamb, 1982). Operations such as time or amplitude stretching, shrinking or transposition could be applied to excerpts of the *sketched* melody producing interesting results with arguable educational value.

Styles as specific as sixteenth century two-voice counterpoint (Newcomb, 1985) and eighteenth century four-voice chorales (Thomas, 1985) have been addressed through ITSs which take advantage of the relatively well-known harmonisation rules for these focused domains. Other work is based on multiple instructional strategies for teaching basic theoretical concepts and how to use them to recognize, play and compose harmonic materials (Sorisio, 1987; Tobias, 1988).

ITS approaches based on cognitive tonal music theories for melody (Narmour, 1990) or harmony (Balzano, 1980) can also be identified in MOTIVE (Smith and Holland, 1994; Smith, 1995) and Harmony Space (Holland, 1989, 1994). MOTIVE is a constraint-based learning tool intended to be used by beginners in exploring the composition of melodies through an iconic interface based on the traditional music notation. Harmony Space is a highly interactive tool for learning about tonal harmony that is based on a representation of the harmonic relationships on a bidimensional matrix. Besides the fact that the interface is not based on the traditional music notation, the evaluation of the system indicates that with some initial guidance novices could easily navigate and produce musically interesting accompaniments. This exploratory tool gave rise to MC (Holland and Elsom-Cook, 1990), a more general framework intended to teach students how to compose tonal chord sequences being supported by a variety of guidance strategies.

Cook (1994) fosters high level compositional skills through reflection, modelling the teacher and the learner in two different roles. He presents a plausible cognitive model of how composers perceive tonality while composing. The aim of Cook's system is to engage a learner in some goal-directed, problem seeking activity in music composition and to foster the student's own ability to be reflective about the learning. In more recent work, a Knowledge Mentoring framework was used to investigate the teacher-learner interactions in the domain of musical composition, providing a taxonomy of the pedagogical goals involved in a mentoring-like way of teaching (Cook, 1998b). A teaching agent based on this framework was developed and evaluated, and the results indicate potential for the design of ITS for other domains, such as the teaching of social science, that rely on creative, metacognitive and critical thinking (Cook, 1998a)

Musical composition is not a well-defined task, and its goal could be defined as to "compose something interesting" (Levitt, 1985). As a result of such an open-ended domain, techniques ranging from interactive games without any kind of guidance to highly focused ITSs with multiple teaching strategies to support the specific needs of the students can be identified.

7 Conclusions

Computers in music teaching, in general, focus on specific tasks related to typical musical activities in an attempt to minimise uncertainties from such an open-ended domain. A number of teaching strategies ranging from simple concept presentation to more exploratory strategies have been adopted to achieve the particular educational goals. For simple musical activities such as teaching the fundamentals of music, the programmed learning approach has proved to be appropriate as most of the time these activities involves only comparing the student's answer with pre-stored templates. For the activities involved in music composition and musical performance, the dominant technique is based on cognitive theories of learning. Table 1 relates the reviewed systems with their encoded knowledge and instructional strategies.

There seems to be a lack of a complete cognitive musical theory to support musical teaching activities properly. Some progress in this direction has been made by Camboropoulos (1998) in his general computational theory for musical structure, which attempts to obtain a structural description of any musical surface independently of any specific musical style or idiom. But we suggest that there is more work to do and the search for a complete cognitive musical theory should be a high priority for AI-based music education research.

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System	*Musical Task*	*Instructional Strategy*	*Knowledge*	*Comments*
GUIDO (Hofstetter, 1988)	Music theory Ear training	Programmed Learning Drill & Practice	-	aural training and test system
MiBAC Lessons (Nackid, 1996)	Music theory Ear training	Programmed Learning Drill & Practice	-	Well-designed package for musicians
Music Ace (Nackid, 1996)	Music theory Ear training	Programmed Learning Drill & Practice	-	Easy lessons for young musicians
Practica Musica (Nackid, 1996)	Music theory Ear training	Programmed Learning Drill & Practice	-	Comprehensive music literacy program
Tune Master (Kirshbaum, 1986)	Performance Skills	Exploratory	-	Teach playing by ear using a touch-tablet
Lamb and Buckley (1985)	Performance Skills	Drill & Practice	-	Visual feedback of student performance
Yoshinori and Nagaoka (1985)	Performance Skills	Drill & Practice	-	Graphical display of expert performances
Piano Tutor (Dannenberg et al., 1990)	Performance Skills	Drill & Practice Coaching/Monitoring	User model Domain Curricular	Score following; Expert performance
INTERPRET (Baker, 1992)	Expressive performance	Socratic dialogue Coaching/Monitoring	User model Domain	Performance editing of analysed melodies
pianoFORTE (Smoliar et al., 1995)	Expressive performance	Drill & Practice Coaching/Monitoring	User model Domain	Visual feedback of student mistakes
(Gross, 1975)	Analysis	-	Domain	Check authorship
(Blombach, 1981)	Analysis	-	Domain	Test theory
(Baker, 1989a,b)	Analysis	-	Domain	Test theory
(Robbie, 1994)	Analysis	-	Domain	Test theory
Music Logo (Bamberger, 1974)	Composition	Exploratory	-	Logo microworld
LOCO (Desain and Honing, 1986)	Composition	Exploratory	-	Logo microworld
Object LOGO (Greenberg, 1988)	Composition	Exploratory	-	Logo microworld
(Gargarian, 1993)	Composition	Exploratory	-	Logo microworld
(Lamb, 1982)	Composition	Exploratory	-	Free-hand curve manipulation game
LASSO (Newcomb, 1985)	Composition	Programmed Learning Socratic Dialogue	Domain	Sixteenth century 2-voice counterpoint
VIVACE (Thomas, 1985)	Harmony	-	Domain	Eighteenth-century 4-voice chorale
THE MUSES (Sorisio, 1987)	Harmony	Multiple strategies	User model Domain Curricular	Based on a harmony expert and a tutoring expert modules
Harmony ITS (Tobias, 1988)	Harmony	Multiple strategies	User model Domain Curricular	Constraint Logic used to represent the domain
MOTIVE (Smith and Holland, 1994)	Melody composition	Exploratory	Domain	Constraint-based tool focusing Narmour's theory
Harmony Space (Holland, 1989)	Harmony	Exploratory	Domain	Interactive tool based on tonal harmony theories
MC (Holland and Elsom-Cook, 1990)	Composition	Exploratory	Domain	Cognitive support framework
(Cook, 1998b)	Composition	Socratic dialogue Exploratory	User model Domain	Foster skills through reflection

Table 1: Some music education applications and their represented knowledge and instructional strategies

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An Intelligent Learning Environment for Musical Harmony

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1 Introduction

An ILE [1] intended to teach tonal music harmonisation to novices with some familiarity with music notation is being developed. Artificial Intelligence techniques have been applied to education mainly in domains such as arithmetic and physics, where "good" solutions can be easily identified [1]. This is not true for the chosen domain. Harmony is typically taught through assignments in which the students must develop a progression of chords (simultaneous notes), for given melodies [2]. Different students' styles or preferences may result in equally valid harmonisations. However this is not completely unconstrained – a number of basic harmonisation rules must be learned and applied, and at the same time students should be aware that rules can be overridden or even disregarded depending on special circumstances. In that sense, the contribution of the proposed ILE to AIEd research is an attempt to achieve a real fostering of the student's musical style, in contrast with previous attempts to apply AI techniques to Music Education, most of which are in the form of prescriptive tutors [3, 4] or exploratory microworlds [5, 6].

The foundation on which the environment is based is the unconstrained theory of harmony of Schoenberg [7]. Schoenberg's system is based on carefully designed exercises intimately linked to the theoretical material. Schoenberg claims that while searching for harmonisation solutions by themselves, guided by instructions, the students *"learn not merely to understand the means, but also to apply them correctly"* [7, p.15].

The ILE prototype will rely on a computational model of this theory, on a specially designed student model including a representation of the student's musical knowledge, and on a multimedia interface to help the students to recognize both aurally and visually the musical patterns involved.

2 Instructional Strategies

Several instructional strategies have been used in computer applications in music education [4, 8]. As reviewed in [9], if we consider the student roles ranging from passive to active, these strategies could be ordered accordingly as: *programmed learning*, for concept presentation and exercises involving multiple choice questions; *drill & practice*

[1] We will use this term throughout this paper to refer to the general class of intelligent educational tools. Other terms used by researchers in the Artificial Intelligence and Education (AIEd) area include Intelligent Tutoring Systems (ITS), Intelligent Computer Assisted Instruction (ICAI), and so on.

intended to automatize particular skills; *socratic dialogue* to highlight misconceptions; *coaching/monitoring* to give advice when a suboptimal behaviour is detected; and an *exploratory* strategy, where the student is encouraged to explore a domain freely.

The proposed ILE should be able to use different instructional strategies according to a particular topic being taught. For instance, programmed learning should be used for the presentation of factual knowledge and associated examples, while some drill & practice might be needed for developing basic skills. On the other hand, a more active role is required from the pupil when determining a sequence of chords himself, while some feedback might be provided through socratic dialogue and/or coaching strategies. In fact, from the very beginning students are encouraged to develop their own harmonic sense of form in the harmonisation of phrases from the simplest cadences to more complex exercises in applying the skills acquired.

3 Curriculum

The curriculum to be taught is made up of lessons that have as *prerequisites* and *objectives* skills directly related to components of the student model. Instructional Design techniques [10] are used to discover inconsistencies in the specification of the skills, lessons and their interdependencies.

The lessons engage the student in well-defined tasks and are used to modularise the instruction. Lesson selection is based on the student model so the system can tailor the instruction delivery according to the individual needs of each student. Inside each lesson, several exercises of different complexity will be developed to provide extensive practice on the particular topic being taught. Also, if the student loses some skill and the same lesson needs to be presented again the system will be able to present a different set of exercises on the same subject.

4 Architecture

The architecture of the proposed ILE is shown in Figure 1 and is based on two main parts: the teaching system and the musical knowledge base. The former is responsible for the appliance of the instructional strategies, as well as keeping track of the progress of the student. The latter contains a rule-based representation of the musical knowledge, analysis and harmonisation algorithms, and an appropriate corpus of melodies and associated harmonisations.

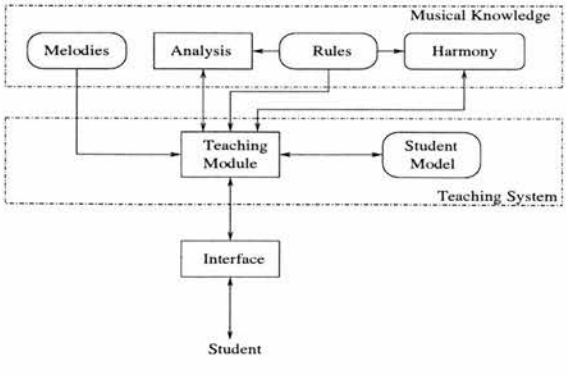

Figure 1: Proposed architecture

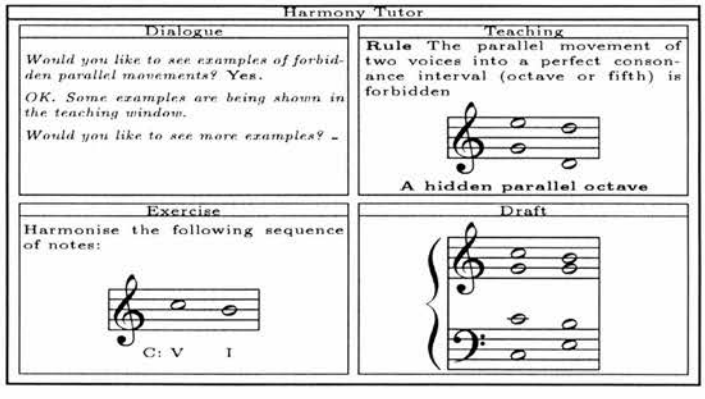

Figure 2: Proposed interaction screen

The *teaching module* governs the working of the system as a whole, deciding how the interaction should take place according to the ability level of the student. The *student model* provides an up-to-date record of the student's characteristics. The assessment of the students' solutions and the harmony development for given melodies are carried out respectively by the *Analysis* and *Harmonisation* processes, based on a set of formalised harmonisation directions kept in the *Rules* module. A proposed interaction screen showing the *Dialogue*, *Teaching*, *Exercises* and *Draft* windows is shown on Figure 2.

5 Evaluation

We will evaluate our model of Schoenberg's harmony rules by comparison of our system's analyses of good and bad harmonisations with those of expert human musicians. The generative aspect of the harmony rules will also be tested by eliciting the opinion of expert musicians on the harmonisations produced by the system itself.

The prototype ILE, including the harmony analyser will then be assessed in the field by expert music teachers, working with 16 and 17 year old music students.

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